Comet Hale-Bopp's Big Show

Enter and Win, See Page 104

ASTRONOMY®

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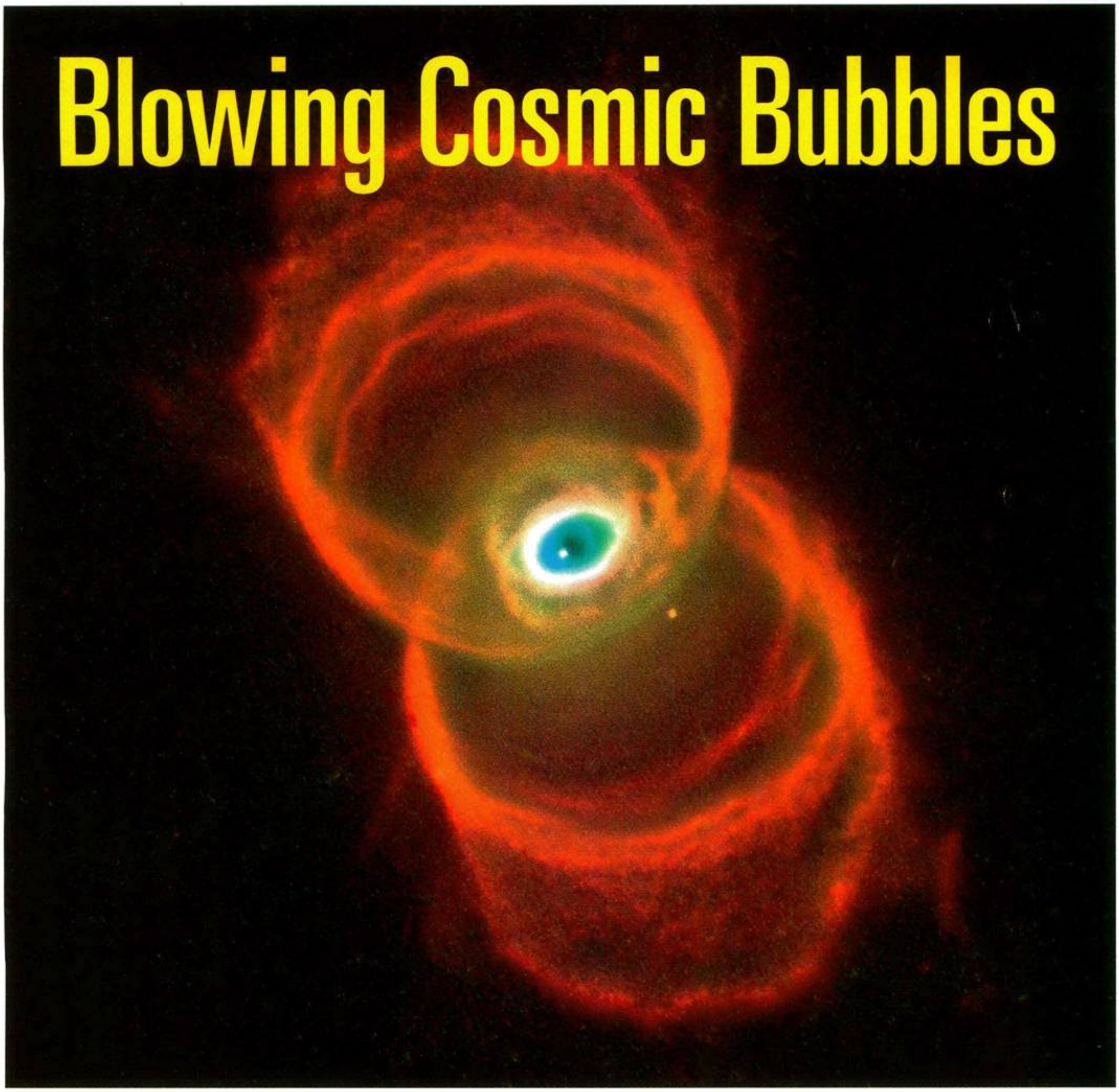
Rogue Comets from Deep Space

Blowing Cosmic Bubbles



- How to Build a Binocular Skyscanner
- Viewer's Guide to the Coming Eclipses

LX50

Advanced technology at the most affordable prices *ever.*

■ Battery-Powered, Completely Cordless Operation! Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ Standard-Equipment Declination Motor and Hand Controller: Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ Multi-Function Control Panel: Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

■ Super Multi-Coated Optics: The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ Massive LX200-type Fork Mounts: Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

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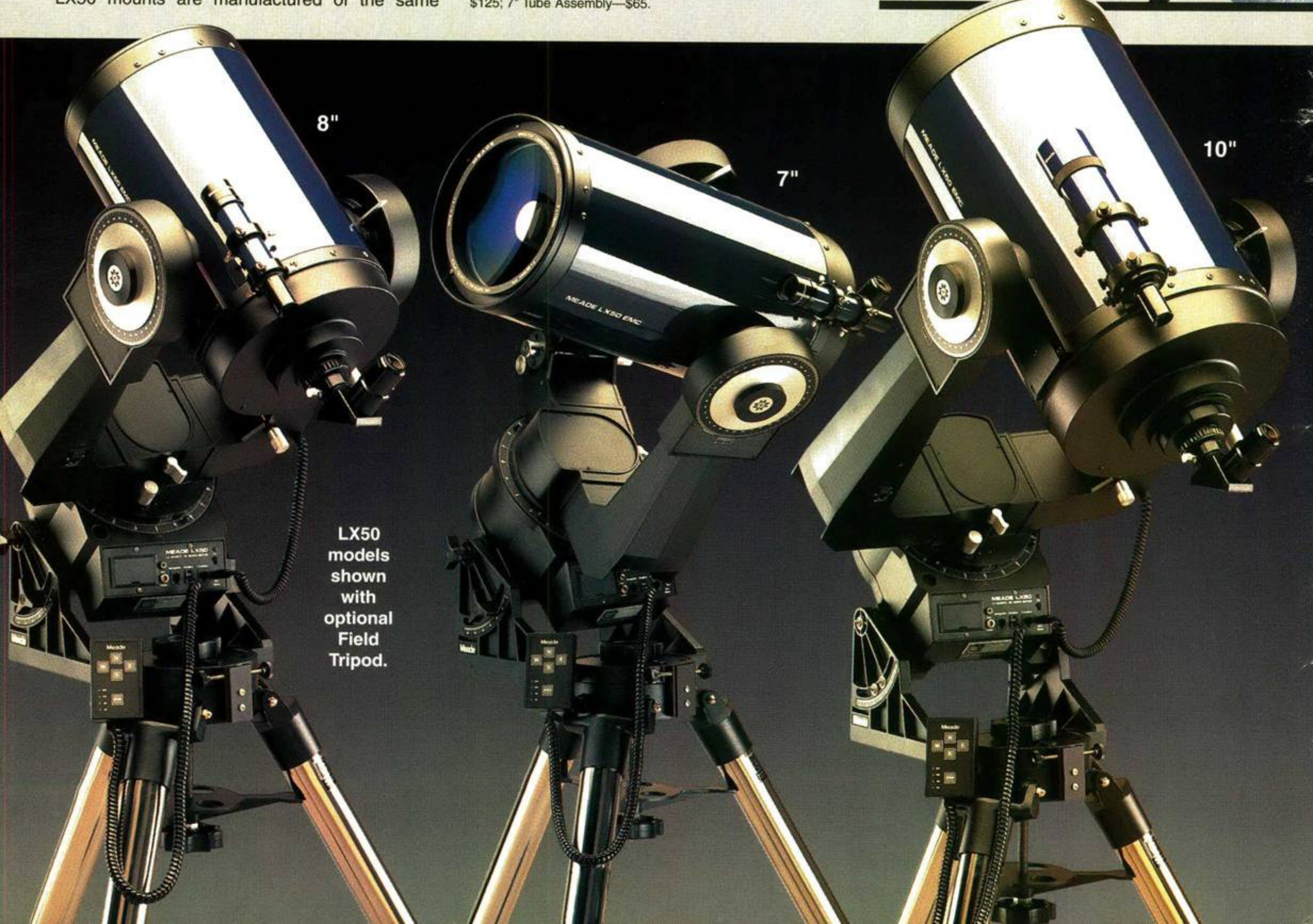

LX50 models shown with optional Field Tripod.

MEADE

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

MEADE LX200 EMC
8"
7"
10"
12"

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states:
8"—$105; 10"—$145; 12"—$215;
7"—$125.

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Prices shown are suggested U.S. mail-order retail prices.

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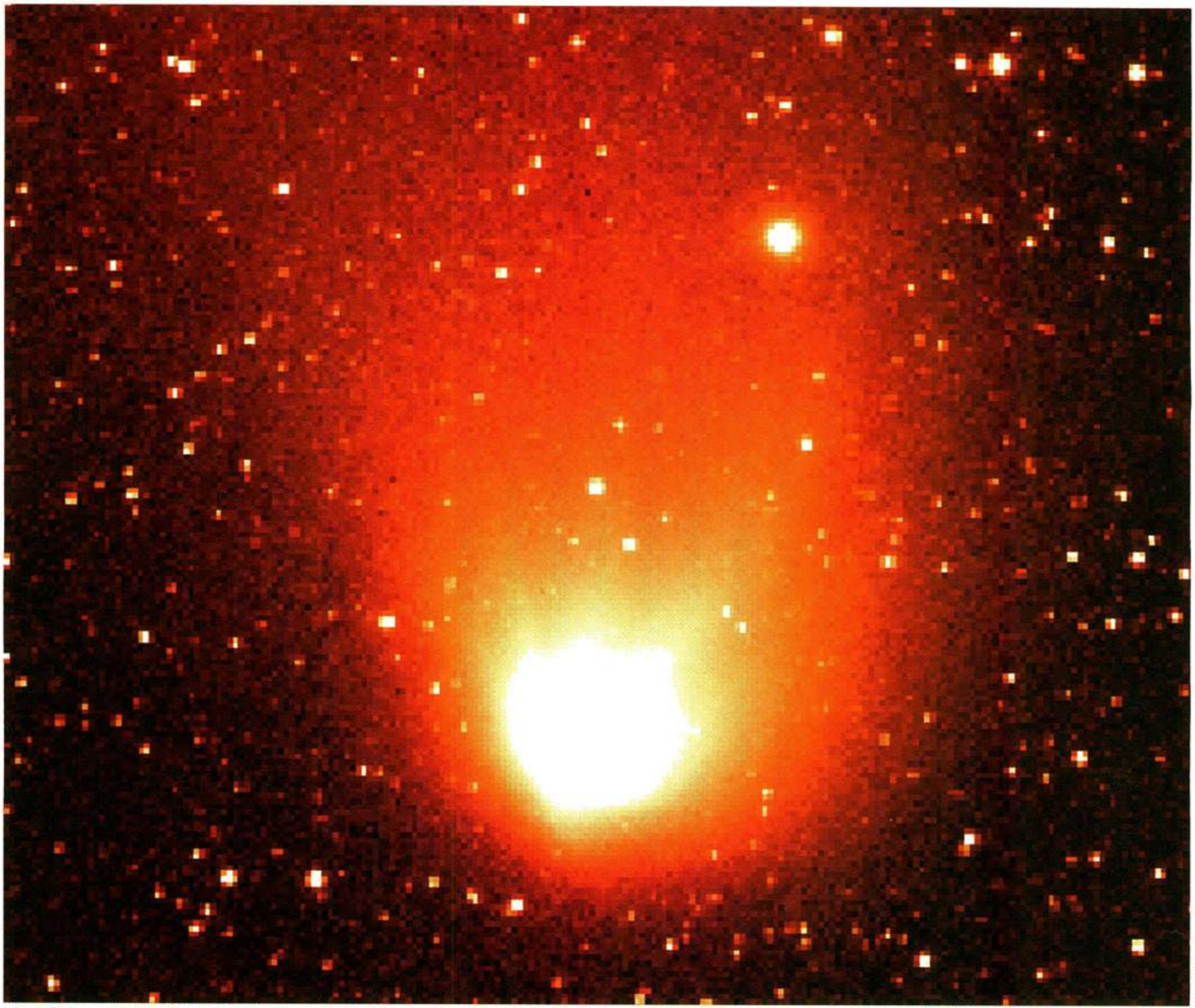


David Hanon

74 Comet Hale-Bopp's Big Show

COVER STORY

36

Blowing Cosmic Bubbles

Astronomers study the beautiful and intricately detailed shapes of bipolar nebulae as they seek to reconstruct the terminal stages in the lives of stars. *Adam Frank.*

Cover photo
R. Sahai and J. Trauger (JPL), the WFPC2 science team, and NASA

46 Seeking Rogue Comets

If theories about how planets form are right, up to 50 trillion interstellar comets may exist between us and the nearest star. *S. Alan Stern.*

54 Toward a New Hubble

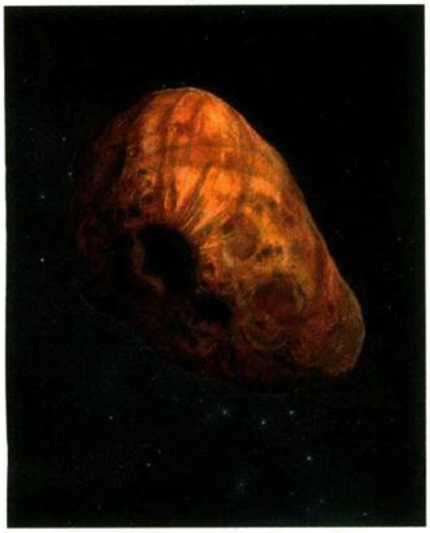
NASA's heading back to the Space Telescope to install two new science instruments and update its technology. *John Shibley and Richard Talcott.*

60 Young, Bright, and Blue

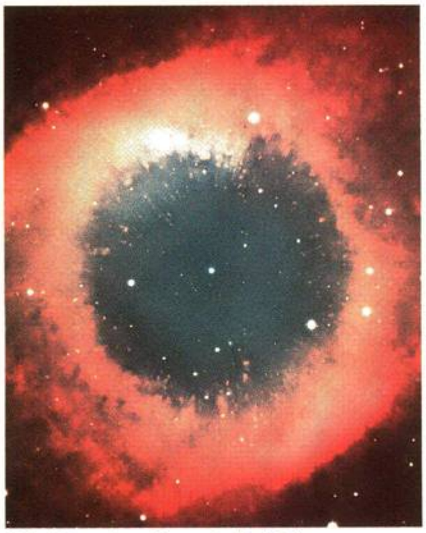
Globular clusters rank among the oldest objects around, but a few newborns show some may still be forming as galaxies collide. *Patti A. Kurtz.*

64 Sky Almanac

Three bright planets hug the predawn horizon, but Mars and Comet Hale-Bopp are this month's top events. *Martin Ratcliffe and Rick Shaffer.*


Bob Eggleton

46 **Rogue Comets from Deep Space**


Anglo-Australian Telescope Board

36 **Blowing Cosmic Bubbles**

NASA

54 **Toward a New Hubble**

74 Hale-Bopp Takes Center Stage
The long-awaited comet approaches its peak appearance. *Patti A. Kurtz.*

80 Get a Grip on Sharper Seeing
Beat the air's attempt to ruin the images in your telescope. *John Shibley.*

82 Stabilize Your Bino-Eyes
Build a portable viewer for binoculars for less than $50. *David Hudgins.*

86 In Search of Faint Galaxies
CCD cameras can capture some forgotten gems. *William A. McLaughlin.*

90 Collecting This Century's Last Eclipses
If the Caribbean in February sounds enticing, just wait til you hear about the spectacular total solar eclipse coming there next year. *Alan Dyer.*

DEPARTMENTS

6 Behind the Scenes
- Go Ahead and Prove It

14 Letters

20 AstroForum
- Russian Space Memories

24 AstroNews
- Hubble Spots Mars' Dust Storm
- Swiss Find 10 New Brown Dwarfs
- More Evidence for Martian Life?
- Ask an Astronomer: A Call for Questions
- Nova Flares in Virgo Galaxy
- Beast in the Core of our Galaxy
- A New Pulsar Planet?

32 Amateur News
- Ideas Spice Up Astrofest
- Star Party Called the Hardy

100 AstroBytes
- RealSky CD
- Eyewitness Encyclopedia of Space and the Universe
- NGC/IC Project

102 Astronomy Books
- The Case for Mars

111 New Products
- Australian Deep-Sky Atlas
- Compact Laser Collimator
- Herschel 400 Logbook
- 4.5-inch Motorized Reflector Telescope

114 Resources and Photofacts

114 Meetings and Events

118 Advertiser Index

119 Reader Reports
- Get Connected with Mars

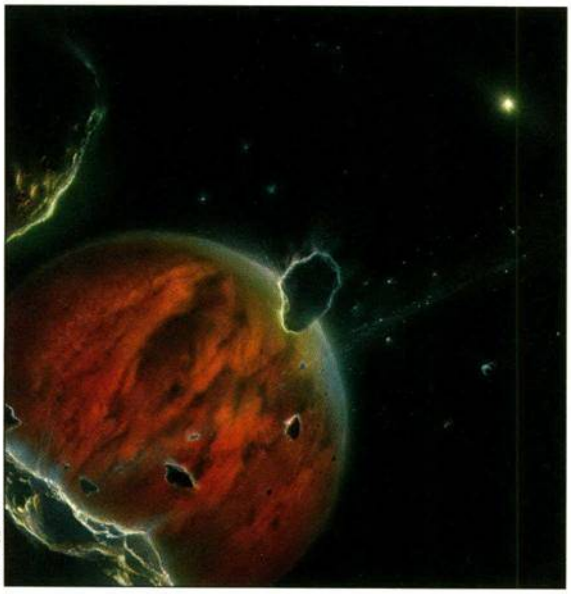
126 Ultimate Exposure

BEHIND THE SCENES

Go Ahead and Prove It

Comet Hale-Bopp is a piece of our solar system, debris left over when the planets were formed. If there are many solar systems like ours in the galaxy — and it seems certain there are —then newborn stars must be spitting out comets by the trillions. Those comets must be ripping around in interstellar space.

"Seeking Rogue Comets," on page 46, tells you why researchers believe interstellar comets often venture into our solar system and it describes the developing effort to spot one. You see, the main stumbling block to believing in rogue comets is simple: No one has ever seen one. No one can prove they exist.


Bob Eggleton

On the subject of unproven heavenly phenomena, we get letters from readers every day. Some worry about theories on the birth of the universe, others worry about theories on the birth of galactic structure. We often answer those questions with good guesses taken from the most widely held astronomical beliefs. When the physical evidence comes in, sometimes the theories hold and sometimes they don't.

Several ASTRONOMY readers met our October explanations of dark matter with skepticism. For example, one reader wrote: "Dark matter in concept is unsettling. Will the real answers be much simpler?" Look to Letters on page 14 and whatever you do, don't miss the answers. Rocky Kolb, an astrophysicist at Fermilab and a member of our new editorial advisory board, has kindly and elegantly answered our readers' queries.

The answers are a treat for us all.

They may push the skeptics toward an understanding of what cosmologists do. They may promote the belief that astrophysicists can successfully puzzle through shreds of evidence and come up with theories that (often) prove true.

Bonnie Gordon

Bonnie Gordon

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MEADE 8" LX10

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Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

All the optical performance of Meade 8" LX50 and LX200 Schmidt Cassegrains...for only *$995!*

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features* — or such a range of important options for special applications. *Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4- pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.

$995. (+ $65 packing & shipping in the 48 states)

LX10 Field Tripod	**195.**
LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

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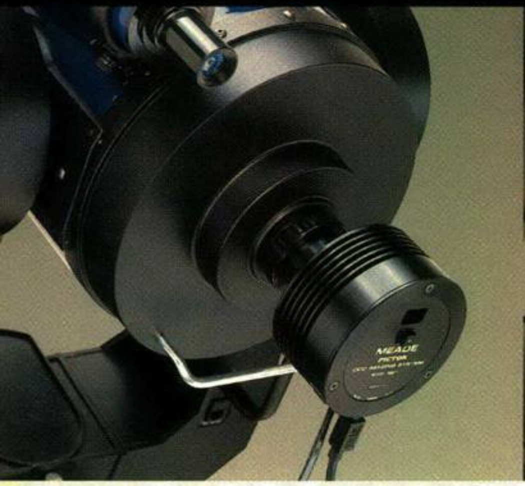
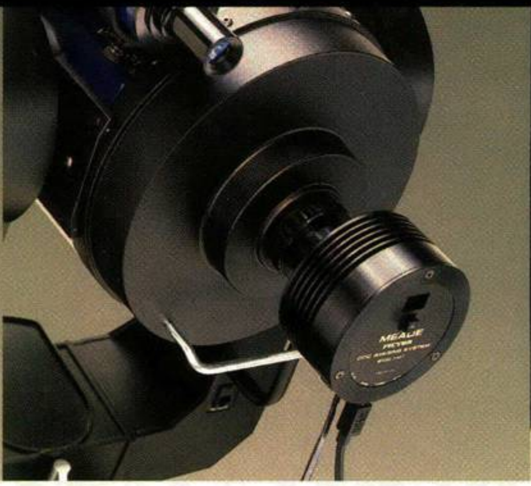
Meade Pictor 208XT
AUTOGUIDER/IMAGER

complete **$495**



Meade Pictor 216XT
AUTOGUIDER/IMAGER

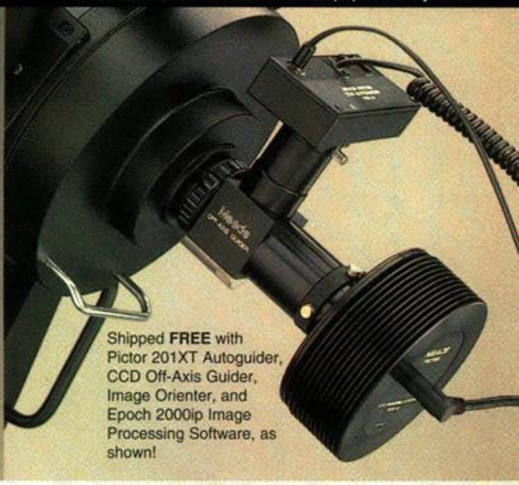
complete **$695**



Meade Pictor 416XT
AUTOGUIDER/IMAGER

complete **$1695**

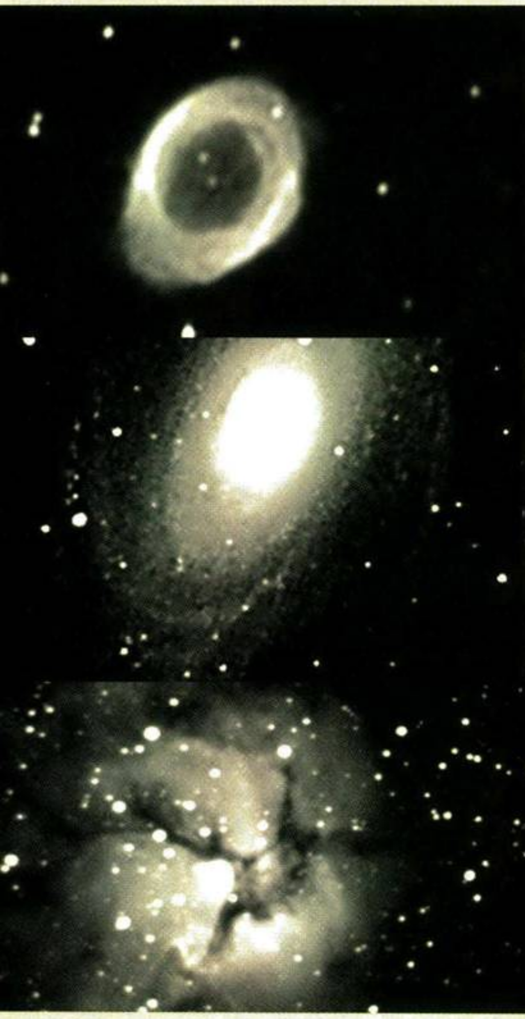
includes $800 Meade CCD Equipment System



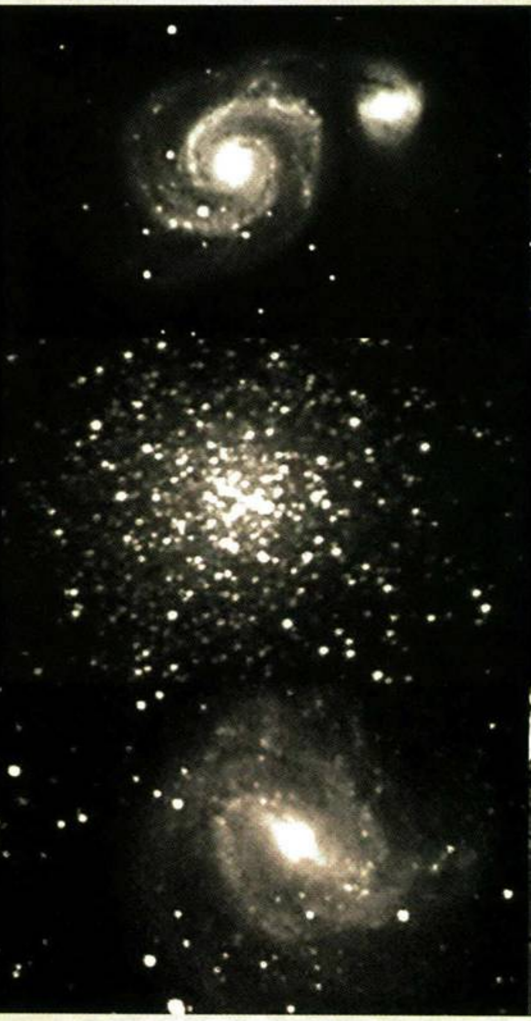
Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment.

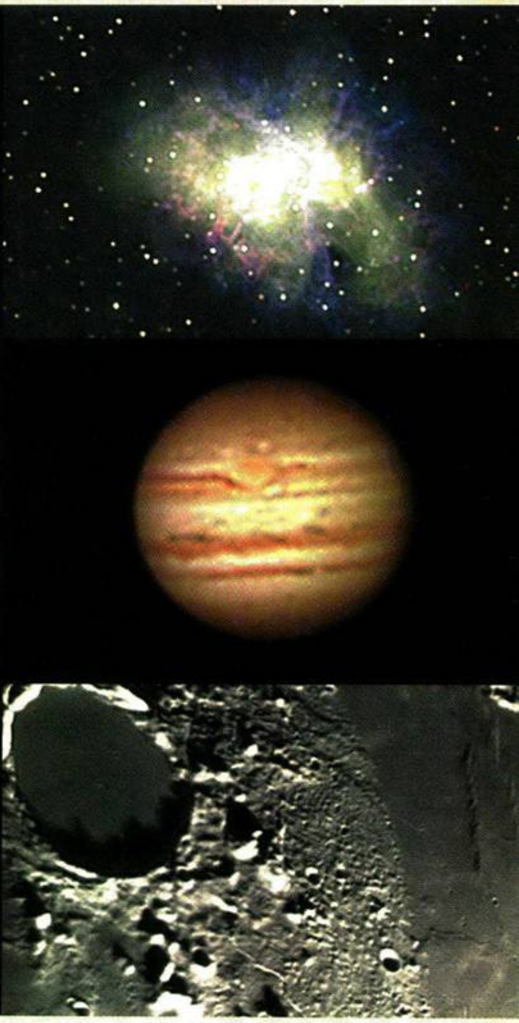
For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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ETX

90mm Maksutov-Cassegrain

Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope— Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

- 1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*
- 1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*
- 3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

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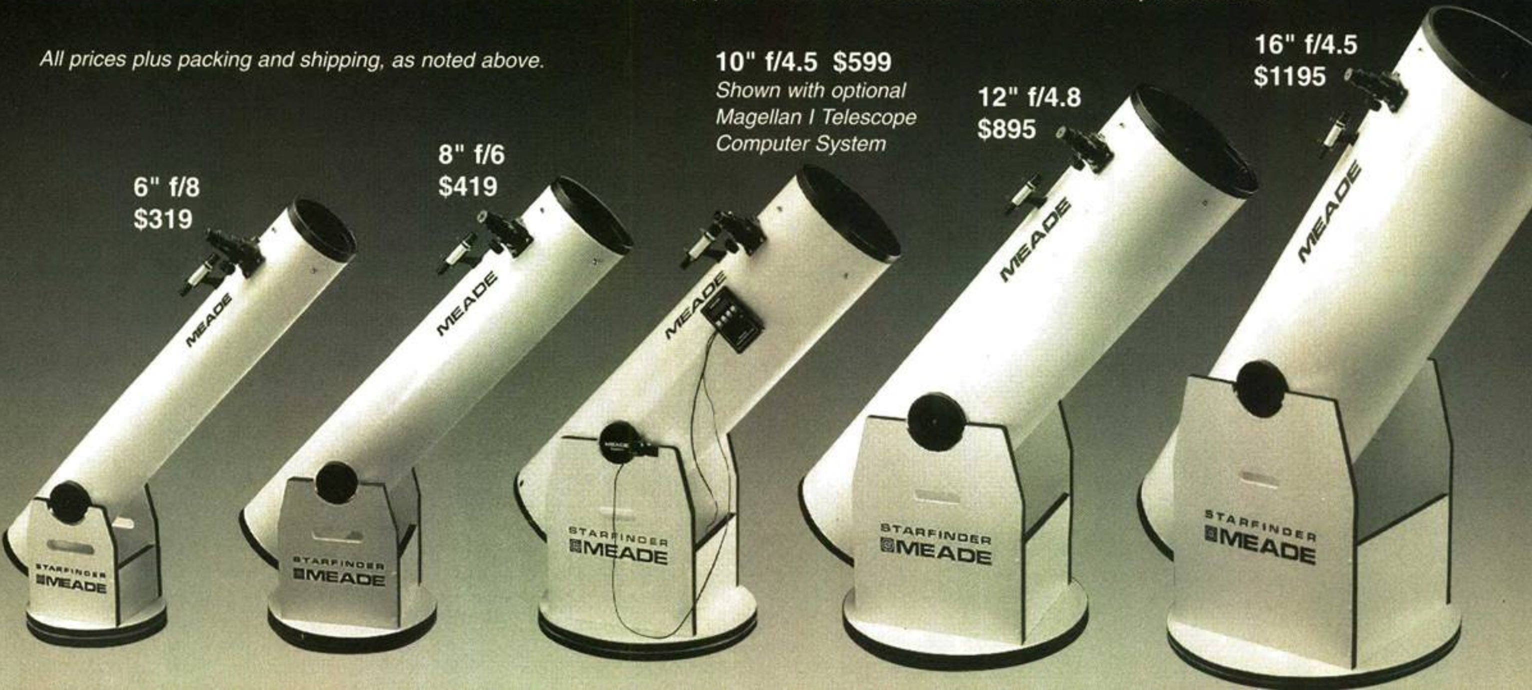
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8
$319

8" f/6
$419

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE
STARFINDER EQUATORIALS

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
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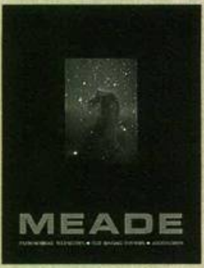
Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*



The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 94-page Meade 1997 General Catalog.

Write, call, or fax Meade Instruments for your free copy!

To Order: Contact your authorized Meade Advanced Products Dealer. Prices shown are suggested U.S.A. mail-order retail prices.

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ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Illinois & Info.: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
16542 Millikan Avenue, Irvine, Calif. 92606 ☐ (714) 756-2291
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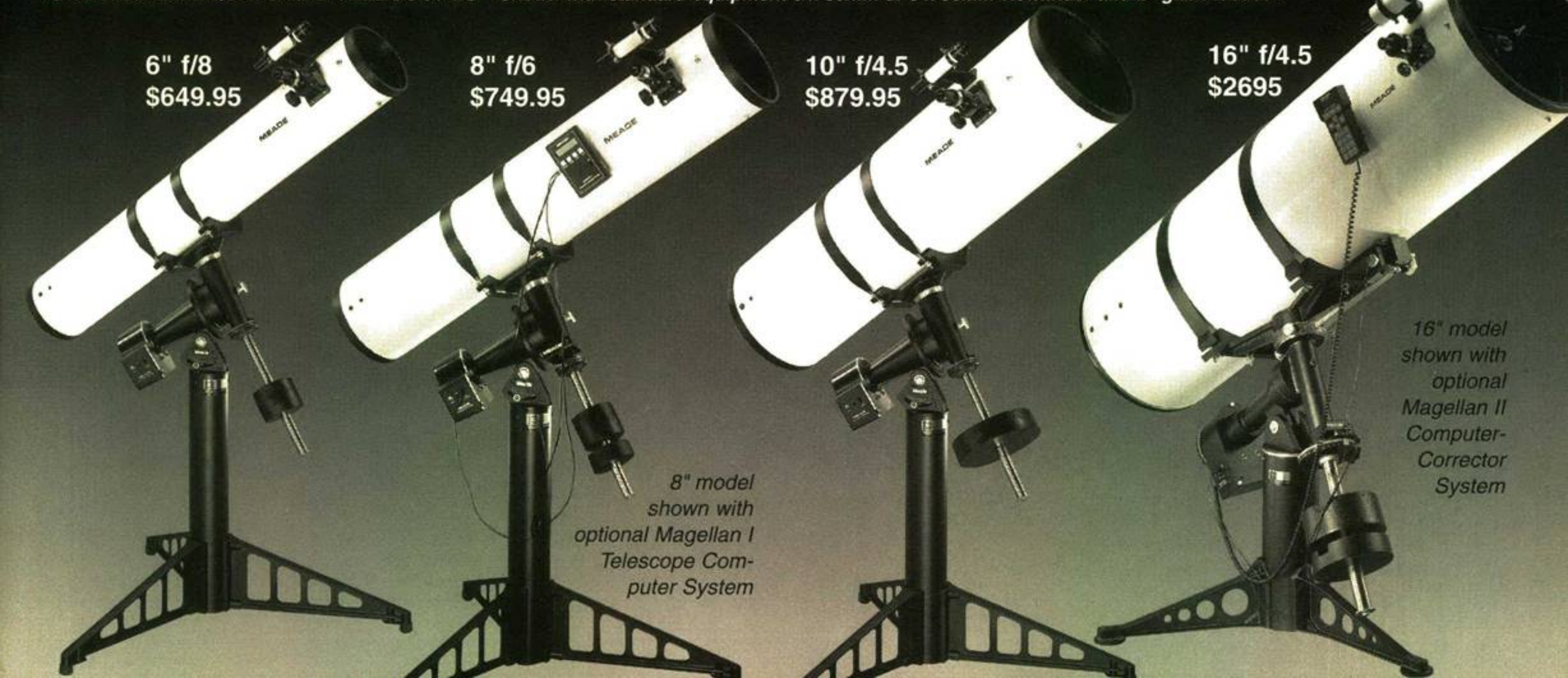
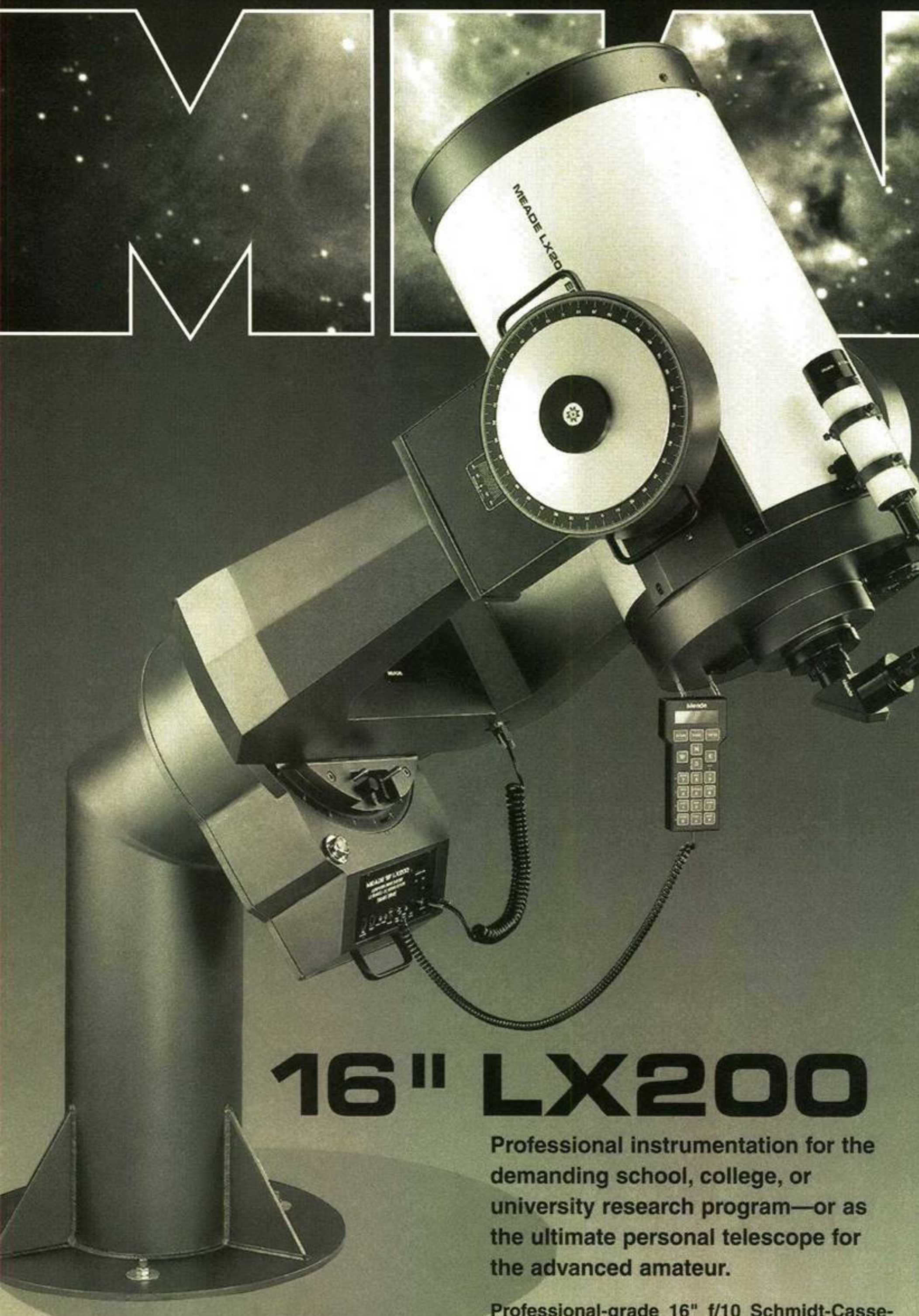
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



8" model shown with optional Magellan I Telescope Computer System

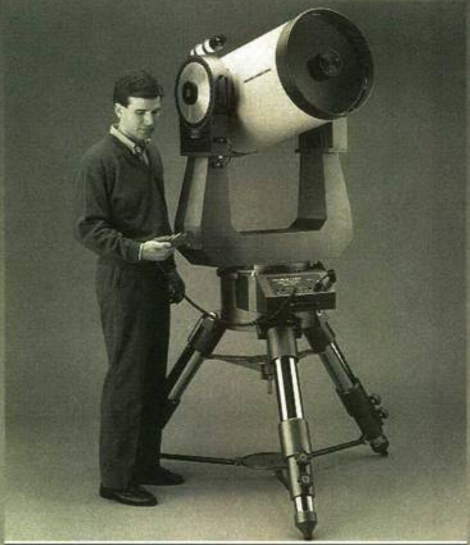
16" model shown with optional Magellan II Computer-Corrector System



16" LX200

Professional instrumentation for the demanding school, college, or university research program—or as the ultimate personal telescope for the advanced amateur.

Professional-grade 16" f/10 Schmidt-Cassegrain optical system meets or exceeds advanced requirements; includes BK7 correcting plate with EMC super multi-coatings for high UV transmission. ■ **Massive one-piece fork mount** permits substantial auxiliary equipment to be piggybacked with rock-solid stability. ■ **Large 11" worm gears** on both axes, with factory-programmed Smart Drive™; periodic error less than 5 arc seconds. ■ **Automatic GO TO capability** to any object in the onboard 64,359-object database or to any input R.A. and Dec. ■ **High-Precision Pointing™** to within one arc-minute in the GO TO mode. ■ **DC servo drive systems** with integrated encoders and planetary gearboxes; encoder resolution: 0.13 arc secs. ■ **Six pushbutton-controlled drive-speed rates,** from photo-guide to fast-slew on both axes, simultaneously. ■ **Microprocessor controlled sidereal-rate tracking** in AZ or EQ modes with quartz accuracy. ■ **Home-Pulse Acquisition** permitting remote alignment and operation through a modem link to the telescope's RS-232 interface. ■ **Control panel connectors** for optional systems including CCD autoguiders and imagers, electric focuser, and the Meade **#1222 Field De-rotater** for long-exposure astrophotography in the AZ mode. ■ Available with **supergiant transportable field tripod** (2-person field set-up in less than 10 minutes); **permanent altazimuth pier** (permitting the entire instrument to be housed in a 2-meter dome); or **permanent equatorial pier** (in cases where piggybacked astrocameras do not permit field de-rotation).



Meade 16" LX200 Schmidt-Cassegrain, with Supergiant Transportable Field Tripod.

Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog, with complete information on more than 40 Meade telescope models.

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The Meade 16" LX200 is in continuous production at the Meade Irvine, Calif. factory. **Delivery time:** 4 to 12 weeks. **Price:** $14,950, complete with supergiant field tripod, plus $385 packing and shipping in the 48 states; prices slightly higher with permanent altazimuth or equatorial pier.

MEADE EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, *are the finest* general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 3000™ Plössls 50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

HOW TO ORDER

- ■ Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes.
- ■ Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price.
- ■ Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
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FOCUS CAMERA, Brooklyn, NY.
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LUMICON, Livermore, CA.
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RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

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EFSTONSCIENCE, Toronto, Ontario.
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- Includes wide-field eyepiece
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- Tube 57 × 9.5 inches
- Diffraction-limited optics
- Includes high-magnification eyepiece
- Extra-stable mount

10-INCH f/4.5 $499.95
- Extremely portable
- Tube 44 × 12.7 inches
- Diffraction-limited optics
- Includes wide-field eyepiece
- Improved mount system

13.1-INCH f/4.5 $799.95
- A BIG scope for less money
- Easy 1-person setup
- Tube 57 × 15.7 inches
- Diffraction-limited optics
- Includes wide-field eyepiece

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VISA *Fax: 1-561-795-9889* MasterCard

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IDENTI-VIEW™
PREMIUM GLASS SOLAR FILTERS
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- **LIMITED LIFETIME WARRANTY**

CLASS "A"
Color band - blue. Class "A" filters are made with the same premium quality polished glass and multi-alloy coating as Class "B". An additional steel alloy added to the coating process makes our Class "A" filters extremely scratch and fade resistant. Excellent for visual and photographic use. Light transmission is 1/1000th of 1%.

CLASS "B"
Color band - white. Class "B" filters are made with polished glass and multi-alloy coating. These filters offer great durability and will provide many years of service and enjoyment with normal use. Can be used visually and for photography. Light transmission is 1/1000th of 1%.

CLASS "C"
Color band - red. Class "C: filters are specifically coated to a lighter density (ND-4). They are for photographic use only. This filter is intended for use by professionals and serious hobbyists. Light transmission is 1/100th of 1%.

ORDERING INFORMATION
1. State scope brand and model number, aperture and outside diameter with filter class and price.
2. Make check or money order payable to J.M.B. Inc. All foreign checks must be payable through a U.S. bank.
3. Shipped free within the continental United States. All others add $5.50 Shipping and Handling per filter. Michigan residents add 6% sales tax. Allow 2-3 weeks for delivery.

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DOME-WORKS™
Dome automation system for any motorized dome. $850. Call for info.

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ASTRO LETTERS

Does Dark Matter Really Matter?

ASTRONOMY received many letters in response to its special issue devoted to dark matter (October 1996). As always, we appreciate hearing from our readers. Rocky Kolb, Fermilab cosmologist and author of Blind Watchers of the Sky, *responds to your questions. Kolb has recently agreed to join ASTRONOMY's new editorial advisory board.*

You have outdone yourselves in the October 1996 issue with in-depth articles about what we don't know, what we're looking for, and the theories and experiments to date. Theories and dreams are motivators for discovery, but what about the facts? Your excellent articles have stirred and intensified my hunger for truth or at least the truth of physical reality. What do we actually know about our surroundings? An article about the facts, not the theories, could give present and future scientific minds a fresh beginning. — *Bonita Nelmes, W. Hazleton, Pennsylvania*

When asked about what we know and don't know, my friend and colleague Joel Primack often quotes Will Rogers, who said that the real problem "is not what we don't know, but what we know that ain't so." The search for the truth of physical reality keeps astronomers awake all night in freezing mountaintop observatories and theorists chained to their desks and computers. Almost all astronomers 'know' that most of the mass of the universe is still invisible to us. Almost all astronomers feel that if we learn the nature of dark matter, many other issues in astronomy will be understood as a result. We know a tremendous amount about our surroundings, but it seems that the more we learn, the more we realize there is to learn.

That is the frustration, as well as the excitement, of scientific inquiry. All of us in astronomy and cosmology share your hunger to know the truth, but are wary of Will Rogers' remark. But I am proud to be a theorist. Everything we 'know,' *from Kepler's laws of planetary motion, to Newton's laws of motion, to Einstein's world of relativity, once started as theories. Theories and dreams are indeed motivation for discovery. — Rocky Kolb*

In order to make the big bang theory work, astronomers must invent objects they have no other reason for believing in. Instead of using facts to construct a theory, they are using a theory to construct facts. Everything that can be explained by the big bang theory can also be explained by normal matter in intergalactic space. This includes the redshift, missing matter, and microwave background radiation. If astronomers stick to the facts, the big bang theory falls apart.
— *Ron Barnes, Affton, Missouri*

Scientists are a contentious lot. A former chair of my department once remarked that the job of the head of an astronomy department is like herding cats. We continuously question the big bang theory and look for something better. But the reason that almost all astronomers use the big bang to understand the universe is that it is the most successful, most predictive, and most complete model of the universe ever constructed. It can explain almost all of the observational facts about our universe.

Whether the big bang will accommodate the few discrepant facts, such as dark matter, remains to be seen. No one knows for sure whether the big bang will remain as part of our understanding of nature. But personally, I think it is a good bet! — R.K.

Each article presented arguments for various sides of the discussion, most of which were based on old ideas of how the universe is "supposed to work." To support these ideas, it appears physicists have invented particles that can't be detected, particles that have no mass (what is a particle, anyway?), particles that are 40 times larger and a trillion times smaller than a proton, and particles that zip through Earth by the billions without touching anything. Yet almost none of these particles can be seen, weighed, contained, measured nor proved to exist.

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ASTRO LETTERS

I encourage researchers to experiment with electromagnetic properties of matter. This would open the door to the New Physics that is necessary to answer these questions and related questions about gravity. — *W. Richard Freeman, Willernie, Minnesota*

Physicists do not invent particles, nature does. Although the particles of nature might be elusive and difficult to detect, sometimes scientists can deduce the existence of a new type of particle from circumstantial evidence. For example, in the 1930s physicists studying radioactive decay of certain elements came to the startling conclusion that either energy was not conserved, or there must be a new type of particle with very small (perhaps vanishing) mass.

On the basis of this circumstantial evidence, a new particle, dubbed the 'neutrino,' was predicted to have the remarkable property that only one out of billions and billions passing through Earth would 'touch' anything. It took more than twenty years before the neutrino was proven to exist, and it is yet to be weighed. Today, there is strong circumstantial evidence for dark matter. Perhaps history will repeat, and one day we will discover that most of the mass of the universe is in the form of a particle different from the neutrons, protons, and electrons of which we are made. It may even be the neutrino! — R.K.

There was a time when the Earth was flat. Honest! All the data we were capable of collecting said so. Until one day, thanks to travelers and time-keepers, a flat planet no longer worked. Aha! A sphere will work. Then an oblate spheroid . . .

Things got worse — all the planets in our sky moved in perfect circles. Then we invented epicycles. Dark matter in concept is unsettling. It could be our greatest scientific invention yet to make our theories and observations coincide. Our current understanding of the universe is so complete that dark matter must exist, right? Remember epicycles were created by the finest minds of the era. Once again, will the real answers be much simpler? — *Dennis Culver, Huntsville, Alabama*

Yes, epicycles were used by some of the finest minds, including Nicolas Copernicus, who had to use epicycles in his theory of a Sun-centered universe in order to make observations coincide with theory.

Sixty-six years after Copernicus, Kepler discarded epicycles when he replaced circular orbits with elliptical orbits. Until Kepler introduced ellipses, the Sun-centered theory of Copernicus was neither simpler than the Earth-centered model, nor was it in much better agreement with observation.

Although not the final answer, the idea of Copernicus was correct. You are right, Mr. Culver, that simplicity and agreement with observation are desiderata of models of the universe. But it is usually the case that even when a concept or model is basically correct, until it is fully developed it does not seem so tidy. I believe that our theories of dark matter today might be like the theory of Copernicus before Kepler: It seems unsettling, unsightly, ad hoc, and unnecessarily complicated, but eventually it will lead to a deeper understanding of nature. — R.K.

Thanks for the Determination and Competitiveness

Reading "Ghosts in the Cosmic Machine" was exhilarating. Just 500 years ago we resolved to be at the center of the universe. Swiftly approaching the 21st century it is clear humankind is far from finished. But MACHOs vs. WIMPs? On occasion modern science seems distastefully competitive.

Prodigious determination and infinite human creativity are at work. Regardless of the pros or cons of scientific competitive ferocity, thanks.

Thank you theorists, mathematicians, cosmologists, astronomers, engineers, academics, and, oh yes, the folks paying to nurture the expansion of human knowledge. — *Bob Ross, Wellington, New Zealand* □

ASTRONOMY welcomes feedback. Send it to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on the Internet, use letters@astronomy.com. Letters may be edited for space and clarity.

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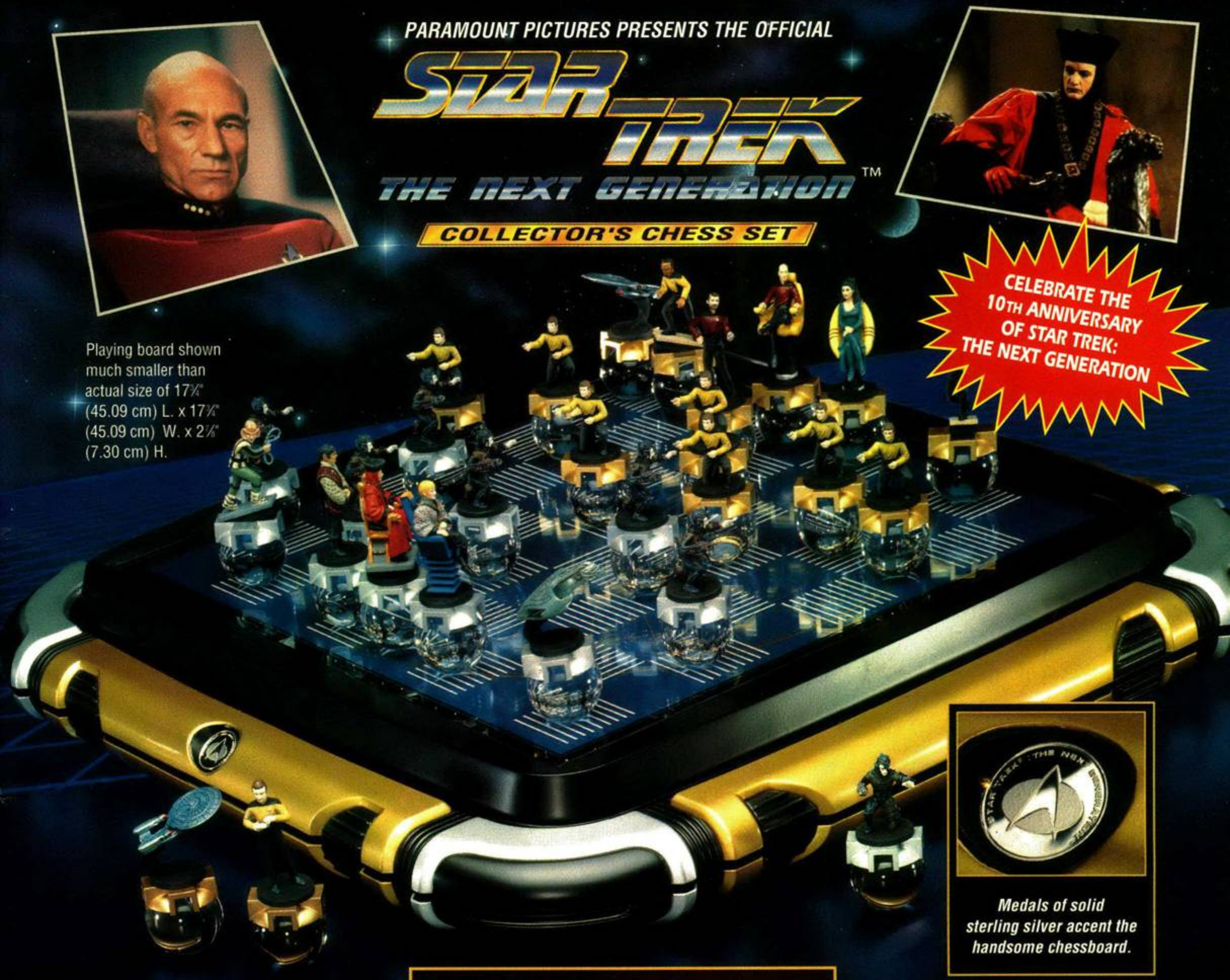
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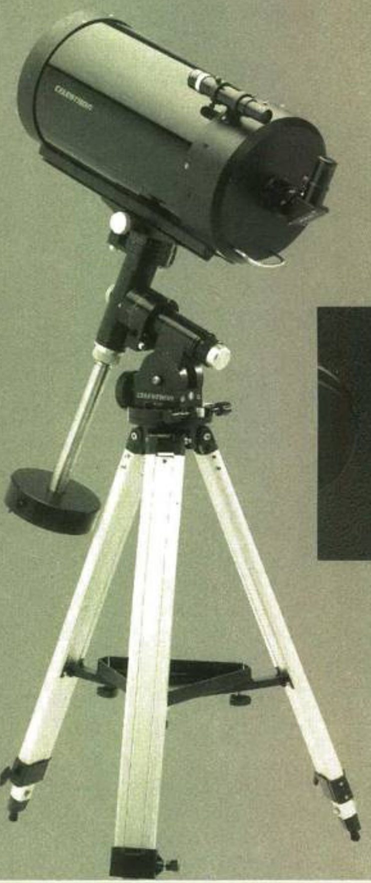

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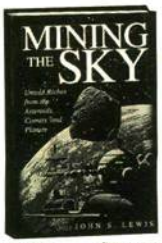
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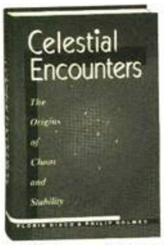
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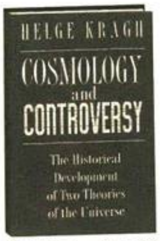
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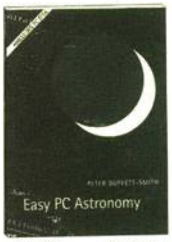
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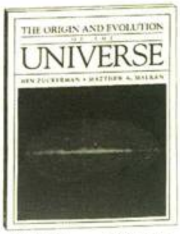
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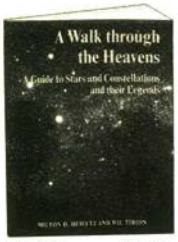
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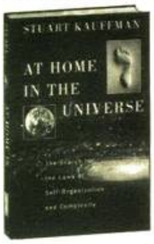
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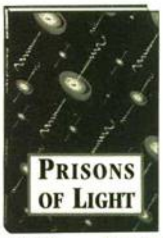
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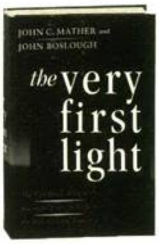
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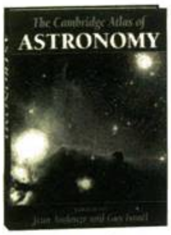
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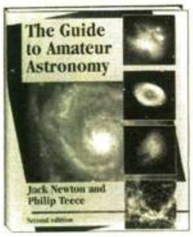
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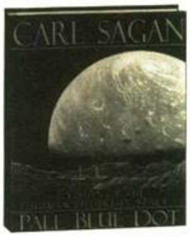
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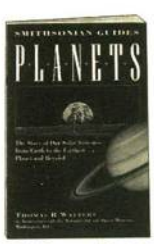
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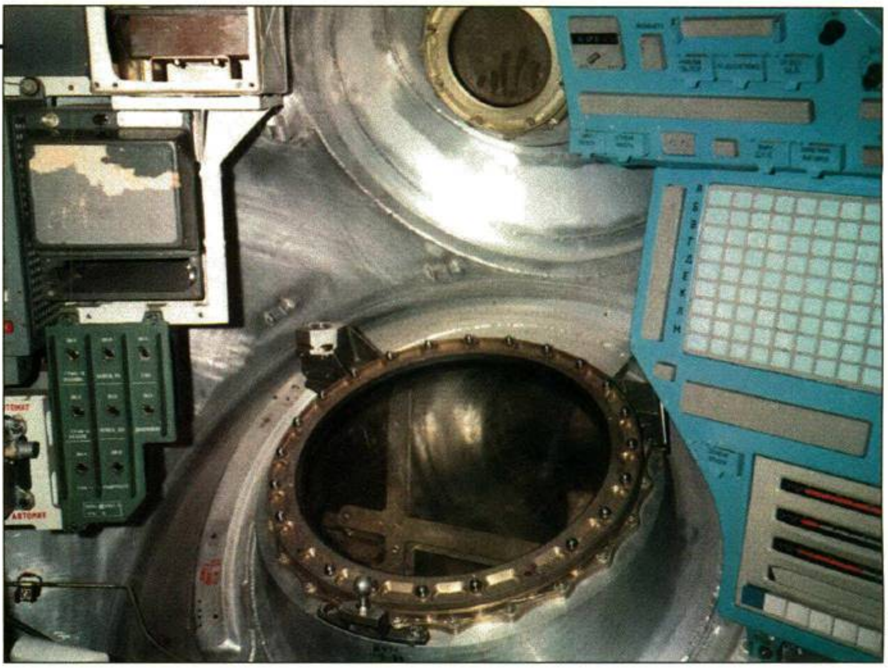
Astronomy 2/97

ASTRO
FORUM

Russian Space Memories

by David S. F. Portree


David Portree

A downward-facing porthole dominates the inside of this Soviet lunar lander that never flew. The cosmonaut would have looked out this window on his approach to the lunar surface.

From high above Moscow, the country that created Sputnik, Soyuz, and the Mir space station looks ideal for astronomy. Hardly any light pollutes the clear, cold Russian sky. "Well, that's one way to look at it," chuckles my seatmate, a British salesman and frequent visitor to Moscow. "The truth is, they just can't afford to keep the lights on."

I'm coming into Moscow for the first Friends and Partners in Space (FPSpace) International Workshop. The workshop is under the auspices of FPSpace, a space-advocacy group organized by volunteer Jennifer Green, an American space station engineer, and two leading Russian aerospace institutes, the Bauman Moscow State Technical University and the Moscow Aviation Institute (MAI).

This workshop was put together essentially through e-mail. The official program began on April 8, 1996, and concluded on April 12, Russia's Cosmonautics Day, a national holiday that celebrates humanity's first flight into space by Yuri Gagarin on April 12, 1961.

Besides having front-row seats to celebrations of Gagarin's flight, workshop participants were offered a rare peek into many parts of the Russian space program's past, present, and future. Here are some of my thoughts from a journal I kept during the workshop.

April 10: A Brush with History

On a distant hill stands a giant statue marking Hitler's farthest advance toward Moscow. We're on our way to Orevo, a military training base 50 miles outside of Moscow. The Bauman University has a facility there.

"No photos," say our guides, "Until we are inside." By now we are used to this edict. Photographing dilapidated old buildings is forbidden, but photographing (and videotaping) their fascinating interiors is okay.

Inside, the business end of a Soyuz capsule faces us from across student desks. Beyond that is a room the size of an aircraft hangar, full of amazing old hardware. Somewhere out there I'm told is a Soviet manned lunar lander, the LK.

After the usual interminable lecture, a technician puts the steering rockets on the Soyuz through their paces. They twitch spastically, simulating the motions they would make steering the rocket toward space.

Perhaps sensing an impending revolt from his audience, the lecturer frees us to explore. The Soyuz steering rockets are attached, it turns out, to a complete Soyuz booster spread out across the floor.

Suddenly, I find my heart is racing. There's an LK standing beside the Soyuz second stage. For 20 years I've heard rumors about the Soviet lunar landing program. First it was denied, then confirmed, then details dribbled out so we barely understood how it worked. Now I stand before a spaceship that might have set down on the Moon ahead of Apollo 11's Eagle, had history turned a little differently.

To our delight, we are told we can climb inside. Reaching the oval hatch involves some acrobatics; obviously, the Russians aren't as concerned about liability insurance as western museum operators would be.

If the Apollo LM is a spider, the Soviet LK is a flea. The egg-shaped cabin is dark and tiny. A lone cosmonaut would have stood before a downward-facing round porthole as he approached the Moon. The LK descends atop a rocket stage called the D block. About a half mile above the Moon, it exhausts its fuel and the LK engine lights up — that is, if all goes well. At that point, there are no provisions for an abort. The pilot would have had only one minute to spot a safe landing place and touch down before he started using his ascent fuel. The LK uses the same engine for final descent and return to lunar orbit.

I grip the hand controllers where a cosmonaut would have stood. This LK never flew, the victim of Apollo's successes. Two of my new friends, Yelena from Moscow and Abigail from Miami, climb inside the Soviet moonship together. I take their picture.

April 12: Gagarin's Legacy

After a quick unplanned visit to the Russian Parliament — which, to the embarrassment of workshop organizers, turns out to be sponsored by ultraright-wing nationalist Vladimir Zhirinovskii — we go to Moscow Aviation Institute (MAI).

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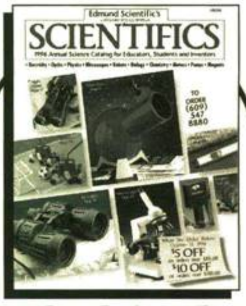

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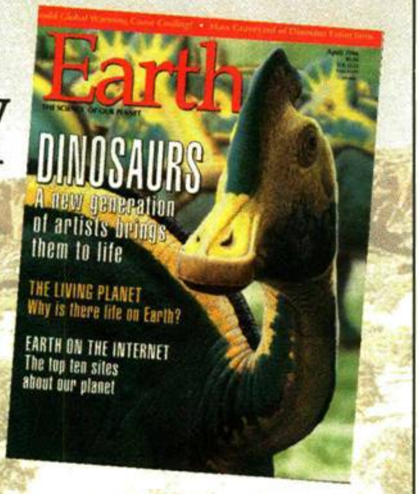
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The Institute houses Lab 601, a hangar-like building that looks like a spacecraft junkyard. Some rockets and spacecraft have been sawed through to create study carrels for students.

In a dark corner, hidden away, I find a plaster bust of the revered father of Russian spaceflight, Konstantin Tsiolkovskii. It's covered with dust and facing the wall. One of the Russian students looks at Tsiolkovskii, shakes his head, and gestures at nearby wreckage. "This is symbolic of our space program," he mutters.

Many students and future engineers hold the same dour opinion. But at the same time a certain pragmatism shines through in their hopes for the future. Freedom of choice and openness now permeates Russia to a degree never before seen in the country. Russians shrug and admit things are now tough, but they just might get better. Their's is a jaded optimism.

Jetting back to America, I realized just how successful the first FPSpace International Workshop was in building bridges. Several participants are now involved in joint projects. For example, two University of North Dakota students cleared the way for an agreement among their school, Moscow Aviation Institute, Bauman University, and FPSpace for joint educational projects using the Internet.

As with the reforms sweeping Russia, the important results of our workshop might take years to appear. We came together to share the common dreams of spaceflight. In the decades ahead, as the engineering students at the workshop become seasoned engineers, the few seeds we planted in a post-Cold-War soil may help pave the way for a joint realization of those dreams. ☐

David S. F. Portree (dsfportree@aol.com) is writing a book on extravehicular activity for NASA. The FPSpace 1997 International Workshop will be held in Moscow April 4-14, 1997. To learn more about it and FPSpace, visit http://solar.rtd.utk.edu/~jgreen/fpspace.html.

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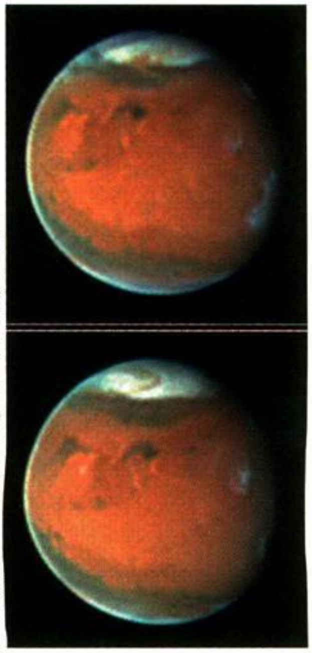
Hubble Spots Mars' Dust Storm

Last September and October, spring began warming the northern hemisphere of Mars. As the Sun climbed higher in the sky, the temperature difference between the frigid north polar cap and the warmer, darker regions to the south generated a large dust storm near the polar cap's edge. The storm stretched for approximately 1,000 kilometers, nearly as wide as the state of Texas.

Although storms of similar size were seen by the Viking spacecraft in the 1970s, this was the first one located near the receding north polar cap. Such storms typically fall below the resolution of ground-based telescopes, but the Hubble Space Telescope's keen eye saw it clearly. (These storms shouldn't be confused with the occasional global dust storms, which often can be seen in backyard telescopes.)

In mid-September, the storm appeared as a salmon-colored notch in the white polar cap. The bright dust also extended over the dark surface surrounding the cap, where it became caught up in the jet stream and blown eastward. The storm had dissipated by mid-October, but a distinctive, dust-colored feature in the shape of a comma curved across the ice cap. Nothing quite like this feature has been seen before. The images also show the edge of the polar cap receding by 200 km during the one-month interval.

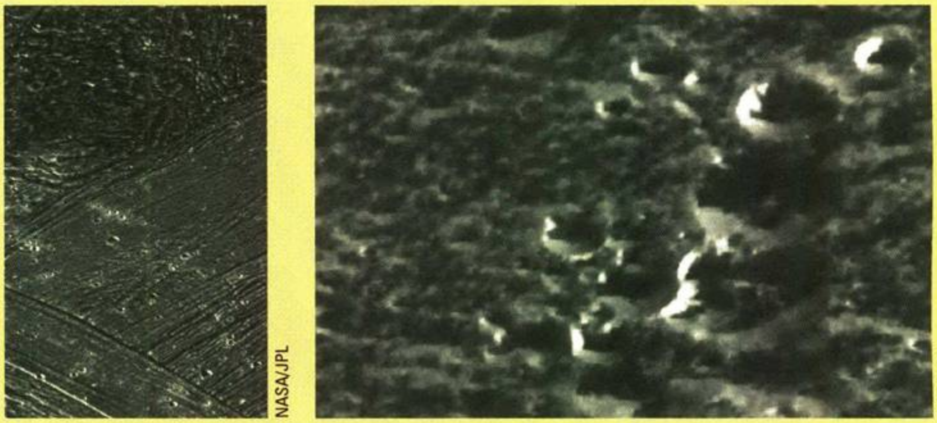
Hubble's monitoring of the Red Planet will help support the upcoming Mars Pathfinder and Mars Global Surveyor missions. The first of these, Mars Global Surveyor, began its 10-month journey on November 7 on top of a Delta II expendable launch vehicle. Once the spacecraft arrives at Mars later this year, it will begin a four-month aerobraking phase to put it into an orbit where it will map the planet's topography, atmosphere, magnetism, and mineral composition.



P. James (Univ. of Toledo), S. Lee (Univ. of Colorado), and NASA

NASA

Last September 18, HST discovered a dust storm in Mars' north polar ice cap. The storm then appeared as a salmon-colored notch in the cap (left, top), but by October 15 it had dissipated, leaving a comma-shaped feature (left, bottom). Mars Global Surveyor, a spacecraft launched on November 7 (right), promises better views when it arrives late this year.



NASA/JPL

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Jupiter's tectonically active moon Ganymede shows a jumble of terrains of various ages in this Galileo closeup of the Nippur Sulcus region (left). At the bottom, ancient dark terrain has been deformed by tectonic fractures and faults. More recent fractures and faults cut across this region in the center of the photo. The youngest terrain lies at the top and can be seen most clearly where it overlays the series of faults that appear as lines in the middle left of the image.

Meanwhile, planetary scientists think they have found evidence for water-ice frost in the far northern latitudes of Ganymede (right). At first glance, the bright arcs seen along the crater rims in this Galileo image look like sunlight reflecting off the craters. However, the Sun shines from the south (right) in this image; the bright arcs lie on the north sides of the craters. Galileo scientists interpret the bright rims to be water-ice frost forming on the cooler, north-facing slopes.

Swiss Find 10 New Brown Dwarfs

Just two years ago, astronomers were wondering whether brown dwarfs existed. Now, brown dwarfs seem to be popping up all over the place. Brown dwarfs form from collapsing gas clouds in the same way as stars.

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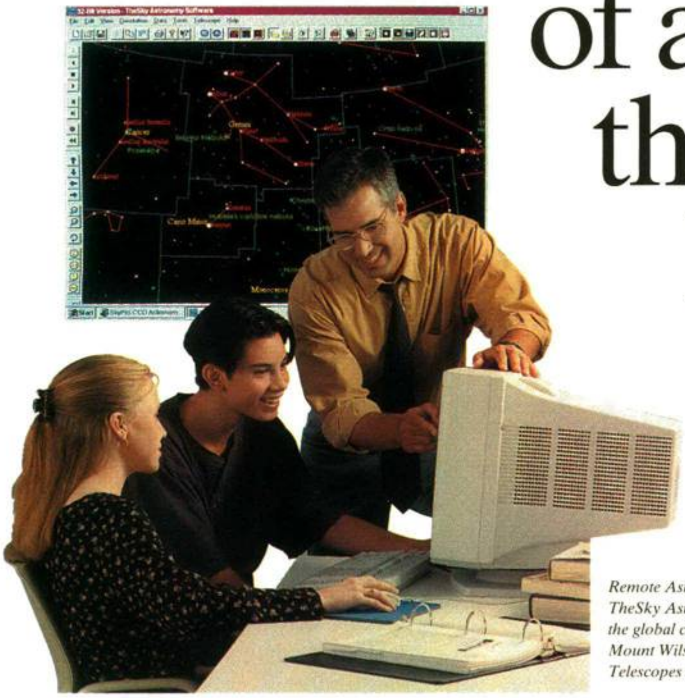

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However, they aren't massive enough to ignite nuclear reactions in their cores, and hence they don't shine like stars. Brown dwarfs can thus be considered as transitional objects that bridge the gap in mass between stars and planets.

Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland have announced the discovery of 10 new brown dwarfs orbiting solar-type stars. Mayor and Queloz found the brown dwarfs using the same method they used to discover the planet orbiting 51 Pegasi. They examined the stars' spectra searching for the back-and-forth motions caused by the gravity of orbiting companions.

The 10 brown dwarfs have minimum masses ranging from 17 Jupiters to 60 Jupiters, and 8 of the 10 orbit their host stars closer than Earth orbits the Sun. However, Mayor and Queloz's detection method yields only a minimum mass. It is thus likely that a few of these objects are heavier than the 80-Jupiter-mass nuclear ignition threshold, which would make them stars rather than brown dwarfs. "But most of them are surely brown dwarfs," says Queloz.

"I think Mayor and Queloz have scored another major coup, they have shed much needed light on the puzzle of what we are finding in orbit around nearby stars," says astronomer Alan Boss of the Carnegie Institution.

Despite these discoveries, it appears brown dwarfs rarely orbit solar-type stars at small distances from those stars. Mayor and Queloz observed 560 stars just to find these 10 brown dwarfs. Several planet-hunting groups who use more sensitive instrumentation than Mayor, such as Geoff Marcy and Paul Butler, have not found any brown dwarfs despite observing more than 200 stars. But these groups have found planets, which are much harder to detect than brown dwarfs because of their lower mass. "About 2 percent of our original sample of stars appear to have brown dwarf companions," says Queloz.

Olivier Hainaut (Institute for Astronomy)

Comet Hale-Bopp bristles with activity in this image taken on September 16, 1996, with the world's largest CCD camera, attached to the 3.6-meter Canada-France-Hawaii Telescope (CFHT) on Mauna Kea. On that evening, Hale-Bopp was 3.1 AU (460 million kilometers) from the Sun. While this two-minute exposure was taken, the Sun's radiation was pushing dust jets from Hale-Bopp's nucleus back into a huge tail. North is at top and east at left.

The CCD camera, built by the University of Hawaii's Institute for Astronomy, is actually eight 2048x4096-pixel CCDs working together as one imager. On the CFHT, the camera covers almost a square degree, enough area to show the entire Moon.

NASA/Johnson Space Center

The football-size meteorite EETA79001 formed about 180 million years ago on Mars and was blasted off the surface during a large impact some 600,000 years ago. It was found in Antarctica in 1979. British scientists have found significant quantities of organic matter inside the rock.

More Evidence for Martian Life?

Three British scientists have reported evidence of life in a second martian meteorite. The meteorite, EETA79001, is only 180 million years old, much younger than the one that generated all the hullabaloo last August.

The team of Ian Wright and Colin Pillinger of the Open University and Monica Grady of the Natural History Museum baked samples of the meteorite to temperatures of 300° to 700° C. The heating process released gases containing the element carbon, the fundamental building block of life. The British researchers say the specific mixture of gases suggests that methane-producing organisms produced the carbon. Many species of terrestrial microbes produce methane as a waste product. "This is a smoking gun for life on Mars," says Wright.

Stanford University chemist Richard Zare, a

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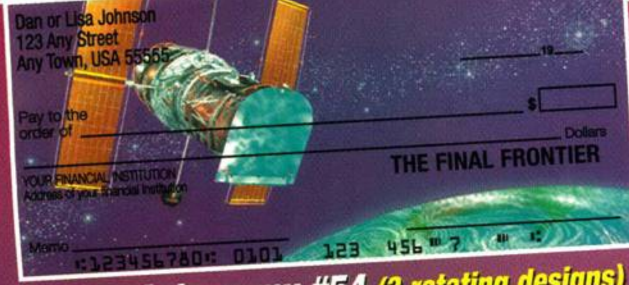

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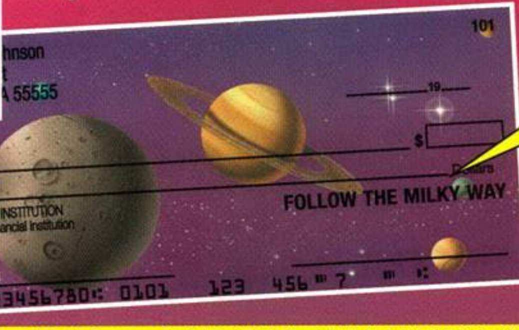

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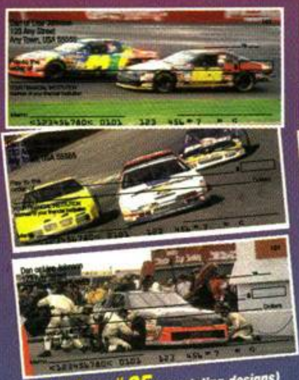

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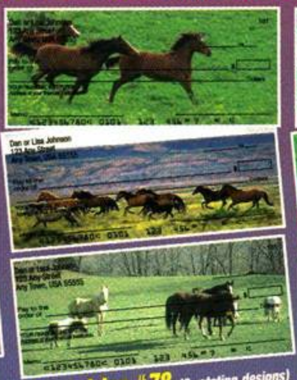

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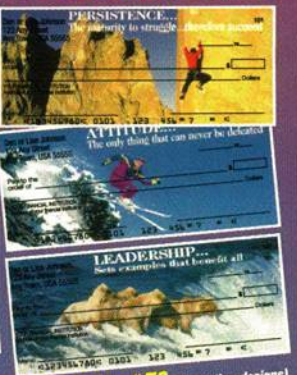

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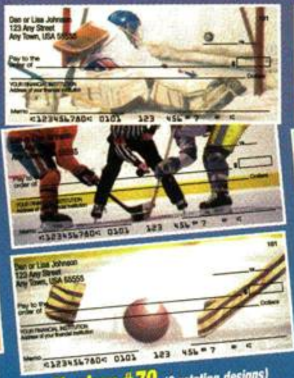

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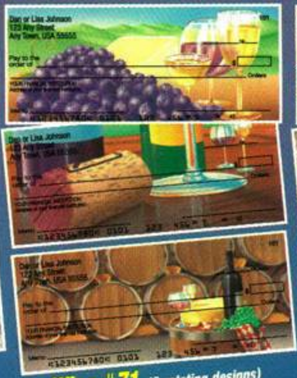

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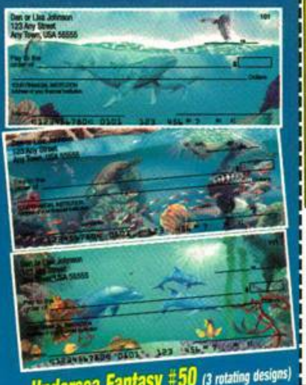

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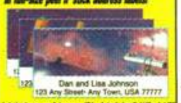

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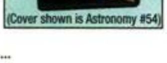

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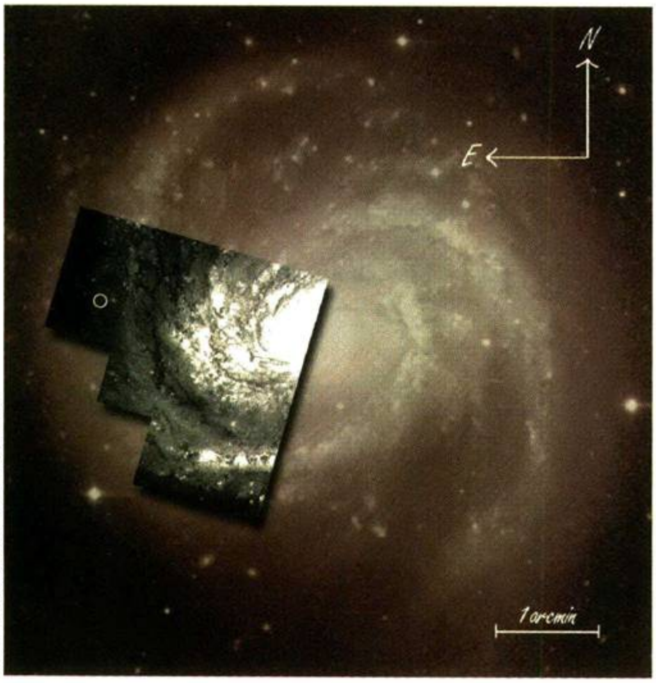
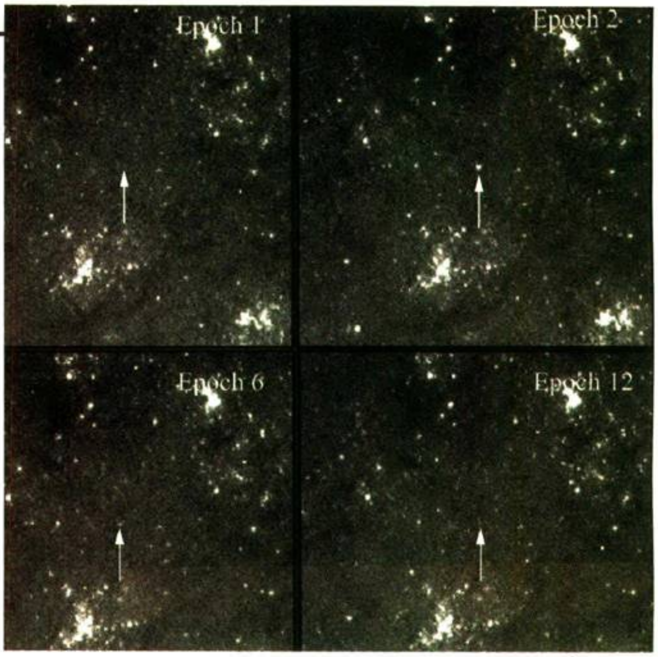


Laura Ferrarese (STScI), et al., and NASA

The Hubble Space Telescope imaged the wedge-shaped region of M100. The nova lies inside the circle.



Laura Ferrarese (STScI), et al., and NASA

Hubble watches the M100 nova (arrowed) brighten and fade. By observing how fast the nova faded, astronomers calculated the distance to M100.

member of the team that reported evidence for life in the martian meteorite ALH84001 last August, cautions that the British research has not yet been reviewed by other scientists. But Zare says if the result holds up, it will have major implications. First, EETA79001 is probably from a different hemisphere than ALH84001, meaning life most likely spread all over the planet. Second, 180 million years ago is practically yesterday in terms of geological time. "It's really quite conceivable that one could go to Mars and find some life-forms that are still alive," says Zare, "because I imagine there are some places with water and hot spots underground."

The British team also found high levels of organic matter in ALH84001, supporting the results reported last August.

Ask an Astronomer: A Call for Questions

Is there a question that you would love to ask a professional astronomer? Here is your chance. University of Illinois astronomer James Kaler, author of last month's article "Extreme Stars," will be answering reader questions in the July issue of ASTRONOMY. If you have access to e-mail, send your query to askastro@astronomy.com. Or you can mail your query to: Ask ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.

Starting with the August issue, ASTRONOMY will be running a monthly question-and-answer column. We'll be happy to take questions relating to either the science or hobby of astronomy. We're looking forward to hearing from you!

Nova Flares in Virgo Galaxy

A nova recently flared up in the galaxy M100 in Coma Berenices, enabling astronomers to calibrate the distance to this member of the Virgo Cluster. The astronomers, led by Laura Ferrarese and Mario Livio of the Space Telescope Science Institute, used the Hubble Space Telescope to watch how fast the nova faded in brightness. Novae are reliable distance indicators because those that decline fast are intrinsically brighter at maximum brightness than novae that decline slowly. Using this method, the team determined M100's distance to be about 53 million light-years.

The team had previously measured the distance to M100 using the pulsation rate of a class of stars called Cepheid variables. "By observing the nova, we were able to determine the distance to M100 independently from the Cepheid distance, and the two turned out to agree very well," says Ferrarese.

Astronomers are keenly interested in determining the distances to faraway galaxies like M100 because this information enables them to determine how fast the universe is expanding, which in turn tells them how old the universe is and whether it will expand forever or contract back upon itself.

Beast in the Core of our Galaxy

Evidence continues to mount that a supermassive

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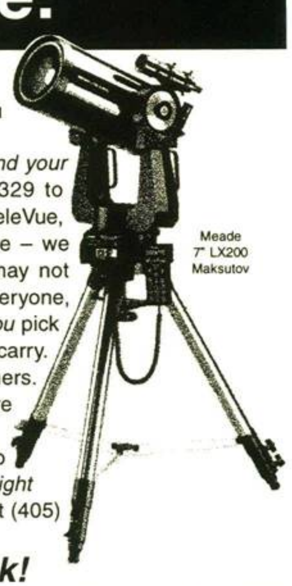
Meade 7" LX200 Maksutov

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New products worth a look – from L-5, Takahashi, Megastar, Optec, and more!

The **L-5 Systems JC524**, shown to the left, is a 24" f/3.8 split ring equatorial reflector with a go-to computer drive – at a price nearly $10,000 less than another manufacturer's 25" model. At $14,900, plus crating and shipping, the JC524 is not exactly cheap, but it may be one of the best buys in astronomy!

We have the new **Megastar** version 3.0 CD-ROM observing software in stock. It includes the 19,000,000 object Hubble Guide Star catalog, planets, comets, asteroids, full LX200 scope control, one of the most customizable screen display and chart printing systems around – and a bargain price of only $129!

We have **Takahashi fluorite/ED refractors** in stock – the 3.1" FS-78EN on the EM-2 mount; the 4" FS-102EN on the EM-2; the 4" FS-102H on the EM-10 mount with dual axis drive; and more.

We have the **Optec f/3.3 Maxfield** in stock starting at $225. It's the sensibly-priced wide-field telecompressor that converts an f/10 SCT into an f/3.3 speed demon for CCD imaging.

We have **ScopeSaver** observing tables for your LX200 tripod – and **ScopeSaver Jr.** alignment plates that make it a cinch for one person to mount an LX200 on its tripod safely!

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> I would highly recommend Astronomics to anyone interested in astronomical telescopes and supplies. My only regret is that I didn't do business with them first. They also supplied one heck of a catalog that far surpasses some of the everyday photocopied ones in both quality and content. **Customer Quote of the Month #59**

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black hole reigns supreme in the core of our Galaxy. Andreas Eckart and Reinhard Genzel of the Max-Planck-Institute for Extraterrestrial Physics in Garching, Germany, have pounded one more nail in the coffin of alternative explanations.

Over the last four years, Eckart and Genzel have used the European Southern Observatory's 3.5-meter New Technology Telescope in Chile to track the motions of 39 stars lying within 1.3 light-years of the core. Even from our distance of 25,000 light-years, the stars move so fast (a few hundred kilometers per second) that Eckart and Genzel were able to detect their motions across the sky against the backdrop of more distant stars, what astronomers call proper motion. Previously, astronomers looking toward the Milky Way's core had only detected stellar motions toward and away from Earth — the so-called radial velocity — by observing Doppler shifts in the stellar spectra.

The radial velocities of stars near the galactic center have long supported the notion of a central black hole. But one could always argue that radial velocities were much higher than the velocities across the sky. Eckart and Genzel have shown that the velocities across the sky are comparable to the radial velocities. By combining the two velocities, Eckart and Genzel calculated *how fast* the stars are moving around the galactic center. The breakneck speeds indicate a concentrated mass at the very heart of our Galaxy, one that tips the scales at about 2.5 million Suns.

A New Pulsar Planet?

For the last decade, astronomers have been tracking an unusual binary star in the globular cluster M4 in Scorpius, 6,000 light-years away. The binary consists of a pulsar (PSR B1620–26) and a white dwarf separated by about the Venus-Sun distance. For years, slight irregularities in the arrival time of the pulsar's radio signals have hinted at the existence of a third member of the system. But astronomers couldn't tell for sure if the elusive third object was a star or a planet.

A new paper from a team led by Fred Rasio and Kriten Joshi of MIT provides strong evidence that the third object is less massive than a star. The team examined how different masses and tidal forces would affect the pulsar's signals. They found that they could barely explain the irregularities with a very low-mass companion star, but the most likely solution involves an object with a mass between 5 and 15 Jupiters. "I think we all now believe that the second companion is most likely a super-Jupiter or a brown dwarf," says team-member Steve Thorsett of Princeton University.

If this result is confirmed, this would be the second pulsar known to be orbited by at least one substellar companion. Two other pulsars also show strong hints of having substellar companions. □

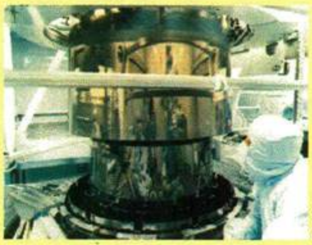
EVENT HORIZON

Russian Mars Probe Crashes

Russia's latest attempt to send a spacecraft to Mars failed when Mars '96 fell back to Earth shortly after its launch on November 16. The first three stages of the craft's Proton rocket booster apparently performed flawlessly. The fourth stage failed to ignite, however, leaving the spacecraft in a doomed orbit. The probe burned up over the South Pacific, scattering debris between Easter Island and the coast of Chile.

To Catch an X Ray

Engineers at Eastman Kodak in Rochester, New York, have just finished installing the final four cylindrical-shaped mirrors for NASA's Advanced X-ray Astrophysics Facility (AXAF), an orbiting X-ray observatory set for a 1998 launch. The mirrors are cylindrical so that highly energetic X-ray photons strike the surfaces at shallow angles and come to a focus 10 meters behind the front of the mirrors. AXAF's largest mirrors are 121 centimeters across, the largest capable of focusing X rays ever made. With its large mirrors, AXAF will be 100 times more sensitive than all previous X-ray telescopes.


NASA

Technicians install the final four mirrors for NASA's next great observatory, the AXAF satellite.

More Kuiper Comets

Three more Kuiper Belt objects were discovered in September 1996, increasing the total to 39. Two of the new objects were discovered by British astronomers Alan Fitzsimmons, Mike Irwin, and Iwan Williams. The other was found by a team led by Eleanor Helin of JPL. All three objects orbit at about the same distance from the Sun as Pluto and are approximately 150 to 300 kilometers in diameter.

Faraway Radio Galaxy

Steve Rawlings of Oxford University and his colleagues have found the most distant radio galaxy ever observed. The galaxy lies some 12 billion light-years away, meaning astronomers observe it as it existed just one or two billion years after the Big Bang. The galaxy appears to be in the process of formation. Although many distant radio galaxies vigorously form new stars, this galaxy is relatively quiescent. Rawlings' team speculates that star formation regions inside the galaxy could be hidden behind gas and dust.

Astronomy! A Brief Edition

James B. Kaler,
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This completely revised edition of Kaler's textbook moves students from their familiar Earth to the distant universe.

It is easier to learn something new when we start with something familiar, exactly how Kaler proceeds in his new book. He starts by relating astronomy to subjects and events students know, progressively moving them out to the stars, the galaxies, and the Universe, each progression building naturally on prior knowledge.

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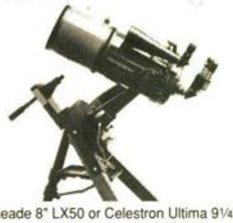

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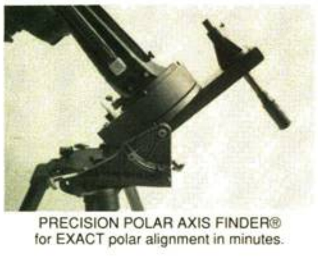

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AMATEUR NEWS

Ideas Spice Up Astrofest

Although the night skies could have been clearer, Astrofest — the largest star party in the Midwest — provided camaraderie, great talks, innovative telescopes, and stunning astrophotos.

The Chicago Astronomical Society hosted this weekend extravaganza for more than 750 stargazers at the 130 acre Camp Shaw-Waw-Nas-See near Kankakee, Illinois, from Friday, September 6, through Sunday, September 8, 1996.

Stephen Saunders, the project scientist for the Magellan mission, was the featured speaker. Highlighting his slide-show tour of the solar system were some stunning Magellan spacecraft images of Venus' surface.

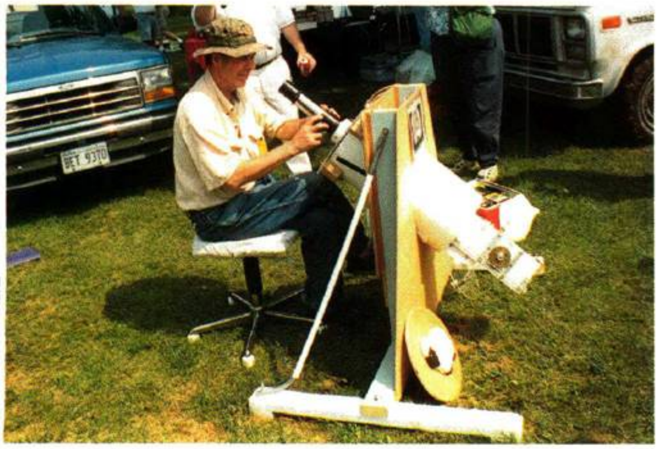
ASTRONOMY associate editor Robert Naeye provided the latest information pertaining to the August 7, 1996, announcement of the discovery of possible life in a martian meteorite. Also speaking were Gary Frey on a remote controlled 20-inch Cassegrain for Photometry and CCD imaging of variable stars, Randall J. McClelland on the "Ben Franklin" bifocal collimator for Newtonian telescopes, Fred Heeren on developments in cosmology over the last five years, and John Jones on star stories in the summer sky.

Wheeling and dealing pervaded the Astro-Swap Flea Market on Saturday. Many folks left vendors with much lighter wallets, but pleased about their purchases. People browsed the telescope field, talking with old and new friends and exchanging ideas and anecdotes. Observing was a challenge due to occasional clouds and high haze, but determined folks managed it in small doses.

Mark your calendars now for this year's Astrofest, set for September 5-7 at the same site.

ASTRONOMY: Patti A. Kurtz

Tom Schultz of Naperville, Illinois, shows off "Molly," his "Mobil Astronomy Observing Laboratory" at Astrofest. This cart was a cooperative effort built by Tom, Greg Johnson (St. Francis, Wisconsin), and Jim Berken (Lombard, Illinois). It is loaded with observing aids and features, and holds Tom's 12.5-inch PortaBall telescope.



ASTRONOMY: Patti A. Kurtz

Getting cold during a winter observing session is not an issue for Jon Nehls because he observes from inside his house. Nehls simulates the operation of his 3-inch f/8 Gerrish refractor telescope, which is built into the wall of his house in Monee, Illinois.

Star Party Called the Hardy

Endurance is a word that comes to mind when describing the Mt. Kobau '96 star party, which took place August 14-18 in south-central British Columbia. There were marathon observing sessions — more than four of the five nights were clear — and an ever-present wind. On most evenings a wind break was the only accessory of value. For planetary observers, Kobau's reputation for steady views did not materialize due to buffeting winds.

But the breezes didn't stop more than 150 enthusiasts from enjoying the sights and sounds for which this mountaintop star party has become famous. Astrophotographers showed off beautiful images between daytime talks. CCD popularizer Richard Berry presented CCD movies of sky motion and Comet Hyakutake. Several people thought they could see Hyakutake's tail rotating about its axis in three dimensions.

Alister Ling

Versatility is the mother of invention for telescope makers like John Casino. His setup combines a 17-inch reflector, ideal for deep-sky observing, with an 8-inch refractor that's perfect for planet watching.

A year's worth of work by telescope makers was also on display: Phil Johnson's portable 6-inch Dobsonian, Denis Boucher's 16-inch Dob that assembles in minutes, and John Casino's 17.5-inch Newtonian that tandems with his 8-inch refractor. As darkness fell, these and other telescopes came to life under a star-filled sky punctuated by streaks of light, the few stragglers left over from the Perseid meteor shower.

Kobau '97 is scheduled for the weekend of August 1. To get more information or register, write Kobau Star Party 1997, c/o Peter Kuzel, 4100 25th Avenue, Vernon, BC V1T 1P4. — *Alister Ling* ☐

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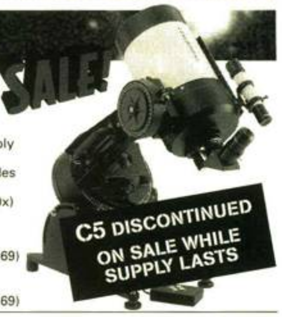

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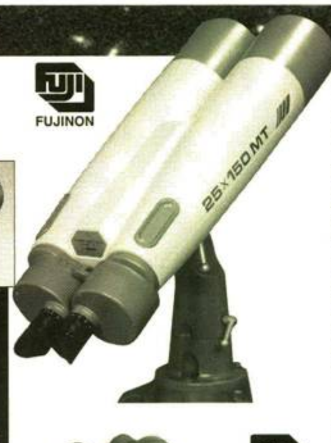

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The Discoverer of Comet Hyakutake

Even at 11th magnitude, Comet Hyakutake was no match for this binocular's colossal 6-inch objective lenses, patented EBC multi-coatings, and 25x magnification factor. The largest binocular in commercial production, its cast aluminum housings are built to U.S. military specs. The views will knock your socks off! Eye relief, 18.6mm. Field of view, 2.7°. Weighs 41 lbs. (Note: The Telescope & Binocular Center's 30-day money-back return policy does not apply on these binoculars.)

25x150 Binoculars	#52458	Call
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Awesome Astro Binoculars

Flat-field optics reduce distortion and astigmatism to virtually undetectable levels. BAK-4 prisms and EBC multi-coatings. Waterproof, tripod adaptable. Individual eyepiece focus.

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10x50 Uncommonly wide 7° field of view for a 10x binocular. Weighs 28 oz.
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Orion 50mm Explorer™

Ergonomic Styling

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10x50 Higher-magnification model with 5mm exit pupil recommended by astronomy experts. Great long-distance daytime binocular. 5.3° field of view.
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10x50 Highest power model, well suited for astronomical observation and distant terrestrial viewing. 6.5° field of view
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Orion 50mm Vista™

Featherlight High-Performance Binoculars

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#9355 $258 (5.19)

10x50 High-power model for general-purpose astronomy and terrestrial viewing. 5.3° field of view. 16mm eye relief.
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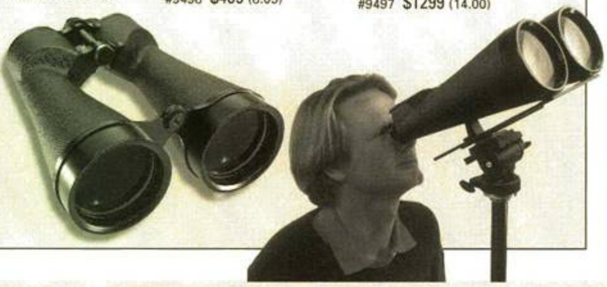

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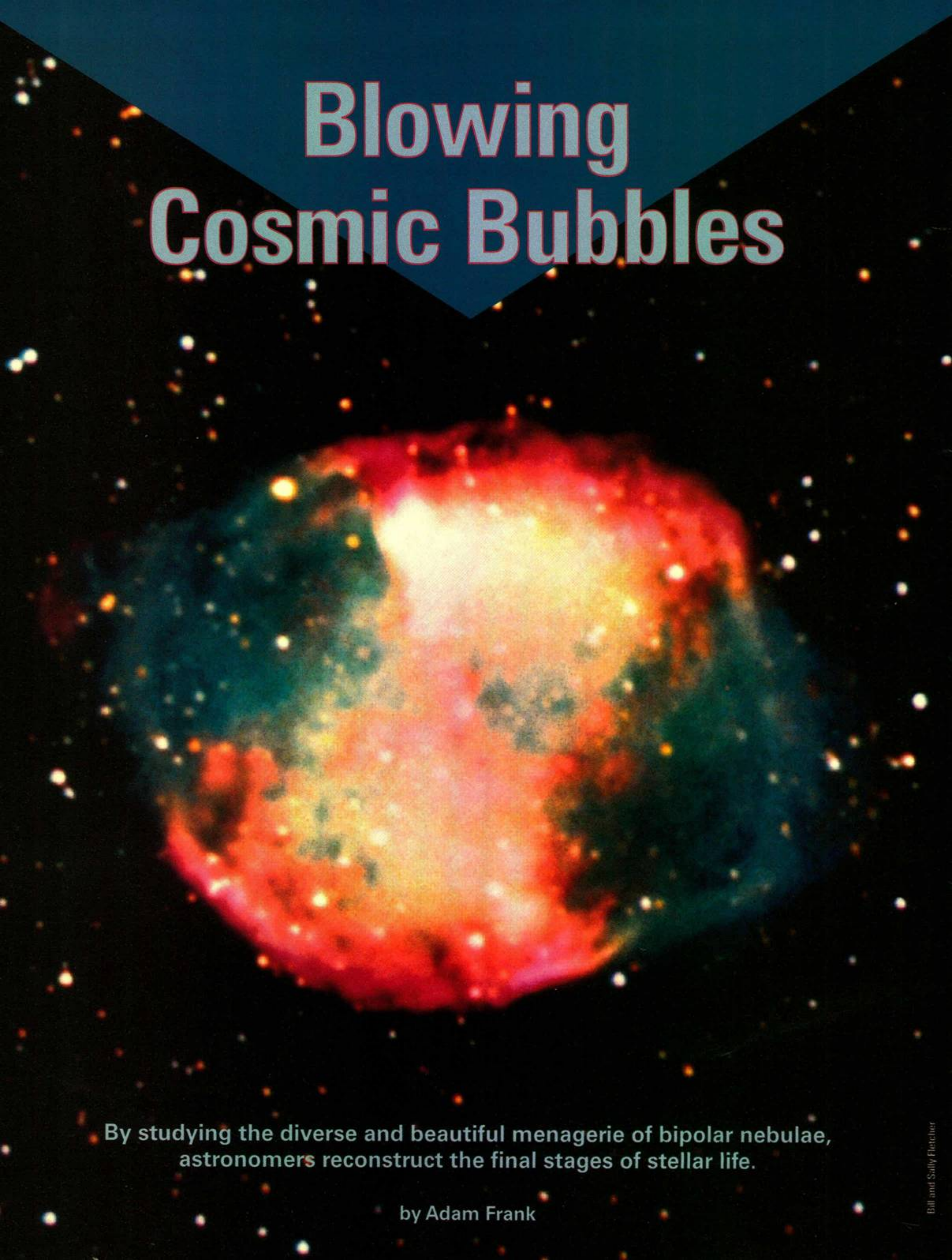
Blowing Cosmic Bubbles



Bill and Sally Fletcher

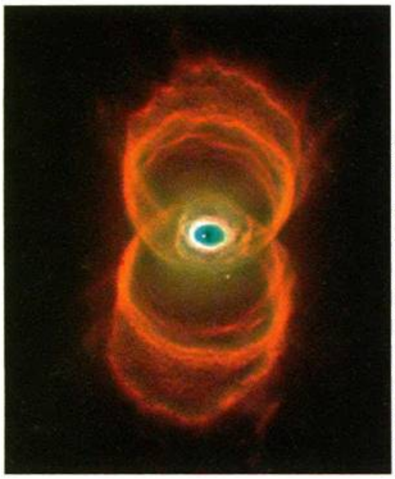
By studying the diverse and beautiful menagerie of bipolar nebulae, astronomers reconstruct the final stages of stellar life.

by Adam Frank

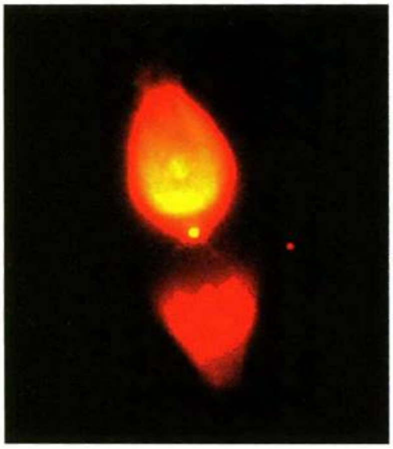
What are the most impressive structures in the night sky? The rainbow bands on Jupiter? Glowing stellar nurseries like the Orion Nebula? How about the vast pinwheels of gas and stars known as spiral galaxies? The forms the universe chooses are beautiful enough to fill any person with wonder and awe. For astronomers though, that profound sense of aesthetics is deepened by the knowledge that history — the story of birth, evolution, and death in the heavens — is encoded within these cosmic architectures.

In the last decade, astronomers studying stellar evolution have found an astonishing variety of hourglass, peanut, or narrow spindle-shaped clouds of brightly glowing gas surrounding geriatric stars. For many researchers, these vast "bipolar nebulae" surrounding dying stars are, arguably, the most beautiful of all heaven's forms.

To astronomers, the term bipolar refers to the presence of two lobes of material moving in opposite directions. Nebula is the ancient Greek word for cloud. The increasing sophistication of astronomical instruments has revealed not only the beauty of these bipolar nebulae but also their power. Some bipolar nebulae contain more than a Sun's worth of mass and all of them are expanding at hypersonic speeds.


Raghvendra Sahai, John Trauger (JPL), and NASA

The Hubble Space Telescope imaged the archetypical bipolar planetary nebula MyCn18, also known as the Hourglass.


Susan R. Trammell, et al., (University of Chicago)

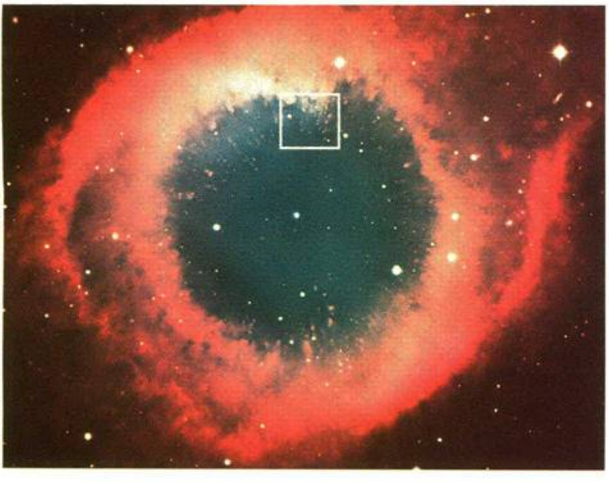
Variations on a theme, part 1: Planetary nebula Minkowski 1-92 formed in a similar manner as many other bipolar planetaries.

At first, astronomers were confused by the variety of form and motion embodied in bipolar nebulae. But as the catalog of these spectacular clouds has grown, so has the recognition that behind their disparate forms lie processes fundamental to understanding the death of stars. Astronomers now see bipolar nebulae as the imprint of violently colliding stellar winds. As a star dies, it drives powerful streams of gas and dust into space. These "stellar winds" sweep up matter surrounding the star into a thin, glowing shell, forming what astronomers call a wind-blown bubble. As the star and the winds evolve, this bubble gets sculpted into a multitude of diverse shapes. Using their new telescopes in conjunction with high-speed supercomputers, astronomers have recently learned to use these luminous gaseous fossils to extract the history of the winds and their pivotal role in the death of stars.

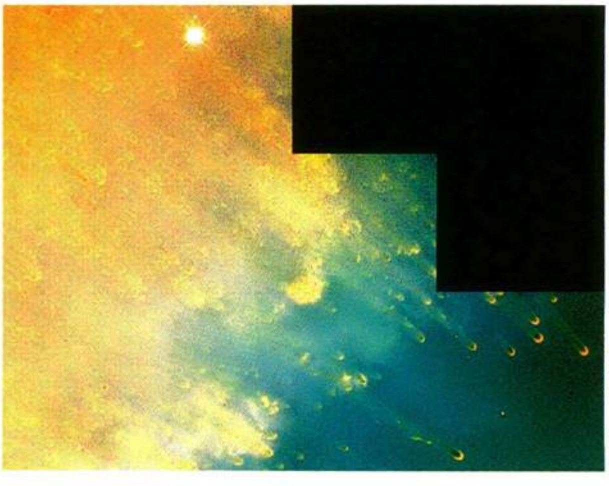
Death by Bubbles: Planetary Nebulae

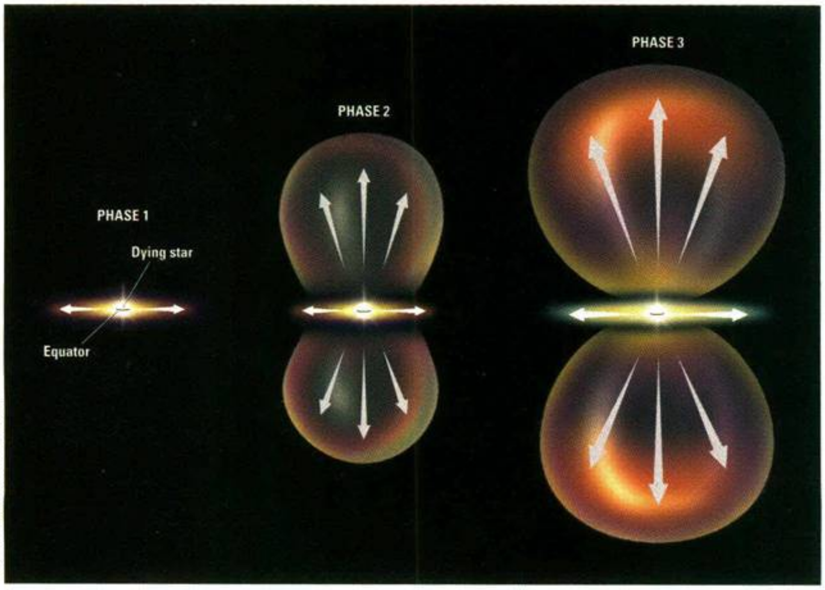
Astronomers have learned much of the language encoded in the fossil bubbles from the study of planetary nebulae. When planetary nebulae were first discovered in the 1700s, they appeared in the crude telescopes of the day as mottled, cloudy disks or rings. The astronomers who first saw them named these features planetary nebulae because they looked

The Helix Nebula (NGC 7293) is a classic wind-blown planetary nebula. The Hubble Space Telescope imaged the boxed area, where one can see colliding stellar winds in action.


Anglo-Australian Observatory/Photography by David Malin

This Hubble Space Telescope detail from the photo on the left shows a fast wind from the Helix's hot, central star ramming into a slow wind ejected thousands of years earlier, creating comet-like knots.


C. Robert O'Dell, Kerry P. Handron (Rice University), and NASA



ASTRONOMY: Elisabeth Rowan

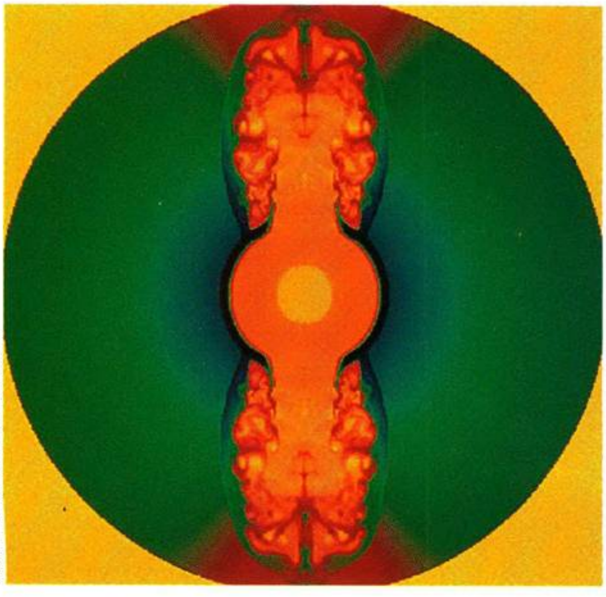
The formation of bipolar nebulae is the tale of colliding stellar winds. In phase 1, the dying star gives off a slow wind of gas preferentially along its equator, forming a disk. In phase 2, a faster wind zooms away from the star more-or-less equally in all directions. It quickly catches up to the slow wind that was emitted tens of thousands of years earlier. The previously ejected slow wind material in the disk impedes the fast wind's progress, while the fast wind remains unchecked above and below the star's equatorial plane. In phase 3, the bipolar nebula assumes the classic hourglass shape. Over the last decade, astronomers have come to realize that this simple model can explain a host of bipolar nebulae that surround many different classes of dying stars.

slightly like planetary disks. But the name is inappropriate because planetary nebulae have nothing in common with planets.

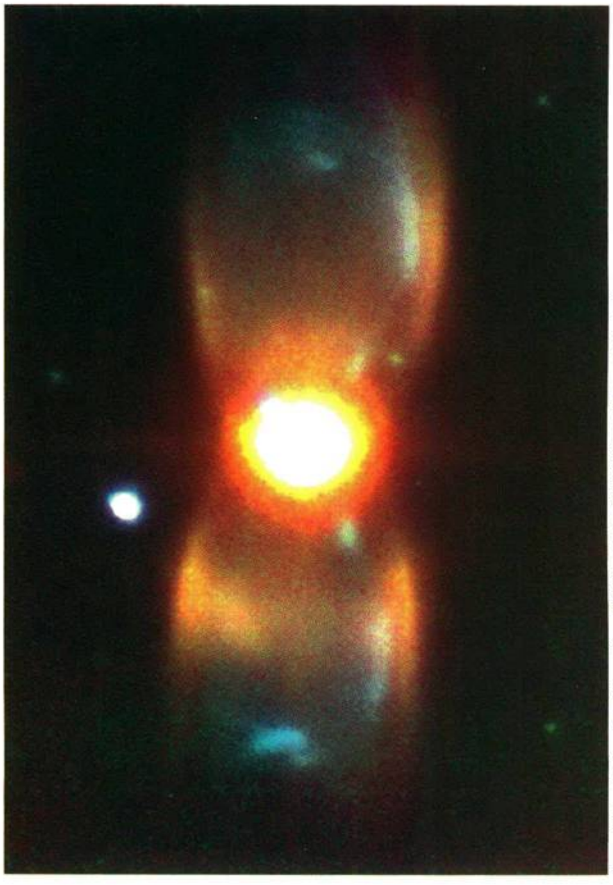
Until recently the image of planetaries as spherical rings of gas, typified by the famous Ring Nebula (M57) in Lyra, has dominated astronomers' perceptions of these objects. The telescopes of the late 20th century, however, have revealed many planetary nebulae to be archetypical bipolar wind-blown bubbles — appearing in an astonishing and baffling array of shapes. In the last decade, theory and observation have paced each other as astronomers used planetaries as a test bed to build a fundamental understanding of stellar winds, dying stars, and the menagerie of bipolar bubbles.

Every star, including the Sun, loses mass as it gives off a wind of hot gas. But the solar wind is just a modest breeze compared to the violent gusts driven off old stars. In a kind of cosmic striptease, aging stars blow their outer layers into space through a succession of winds that change character as the

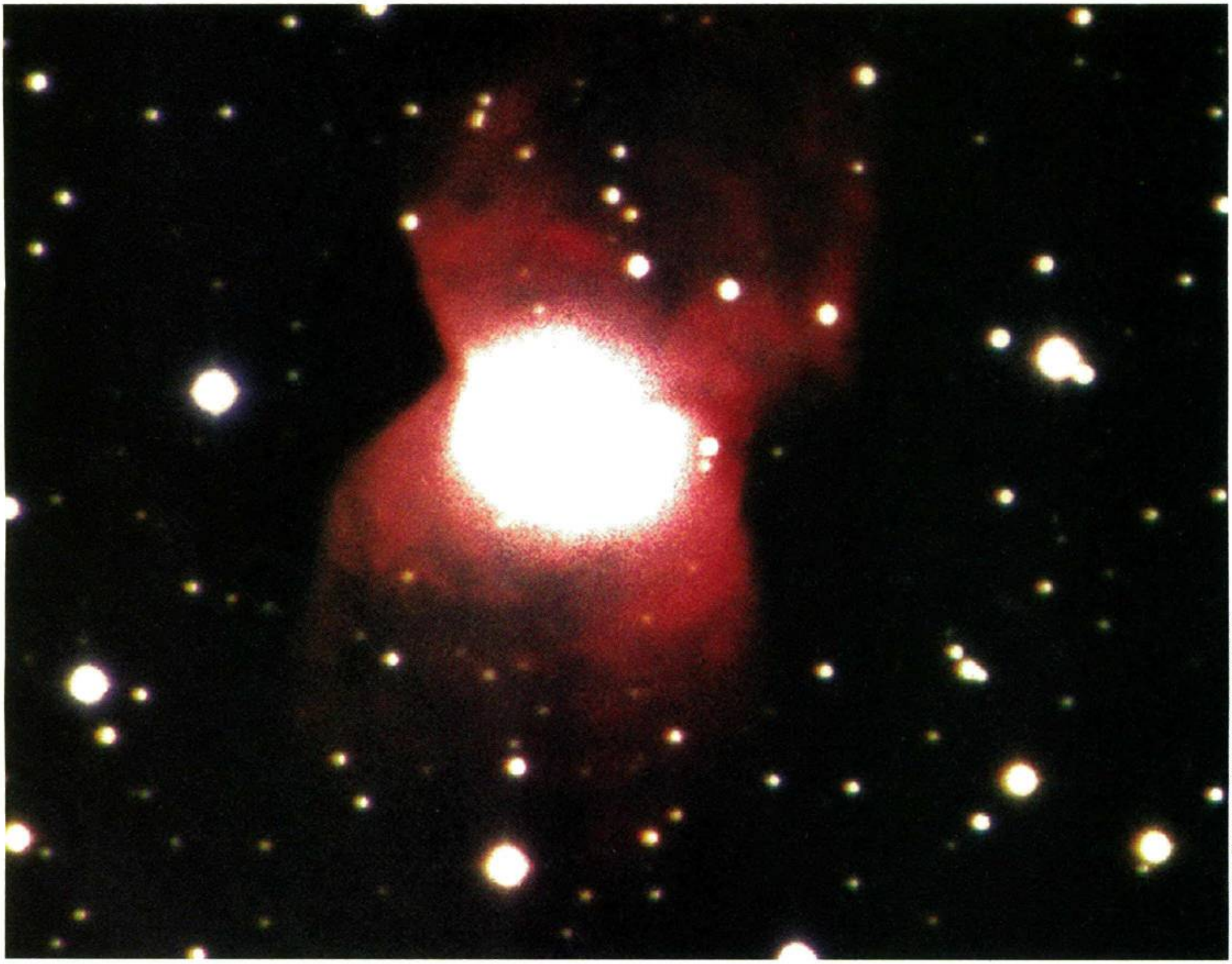
Astrophysicists like Adam Frank use supercomputers to model the formation of bipolar planetary nebulae. The end result (below) often looks remarkably similar to actual planetary nebulae such as Minkowski 2-9 (right), reassuring the scientists that their theories closely match reality. In all of these instances, a dying central star sheds material along its equator, which forms a disk. Later, the dead star gives off a fast wind, which catches up to the disk. The fast wind is pinched off by the disk, forming the hourglass shape.



Adam Frank (University of Rochester)



Joseph Hora (University of Hawaii) and William Latter (NASA/Ames Research Center)



Anglo-Australian Observatory/Photography by David Malin

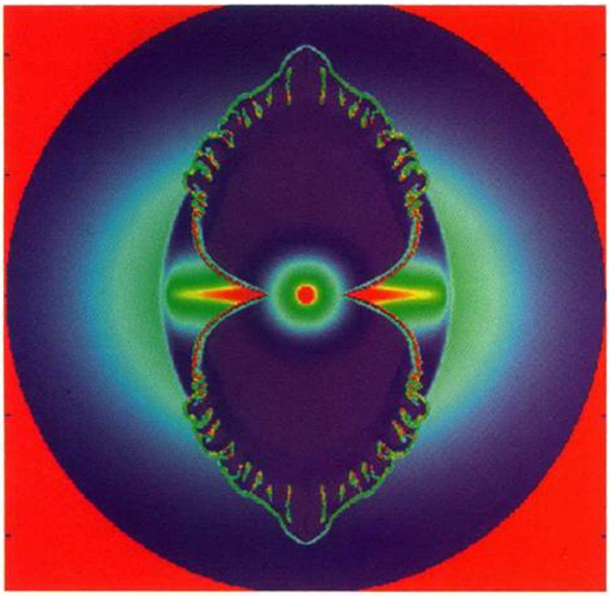
NGC 2346 is another classic bipolar planetary nebula. A fast wind of gas zooms away from the central star's polar regions, giving rise to the bipolar structure.

star evolves. Astronomers believe that planetary nebulae are the last gasps of so-called low- and intermediate-mass stars — stars that begin their lives with less than eight times the mass of the Sun. They also know that when a low-mass star enters its old age it swells up more than 100 fold to become a red giant (see "Extreme Stars," January 1997).

The outer layers of these swollen giants are only loosely bound by gravity, so it is easy for a relatively slow, dense wind to be driven off into space at speeds of roughly 90,000 kilometers per hour. Over tens of thousands of years, this slow wind strips off most of the star's mass, leaving behind a hot, Earth-sized core that has a thin, hot layer of nuclear burning material on the surface. The hot surface gives off a torrent of high-energy radiation, dramatically changing the character of the stellar wind. The wind becomes tenuous but very fast (fast wind speeds have been clocked at more than 18 million kilometers per hour).

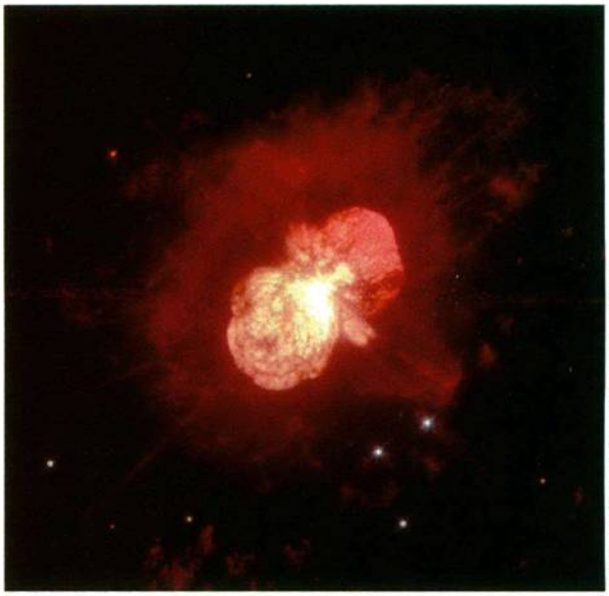
To help them understand the origin and evolution of planetary nebulae, astronomers have turned to an idea that might be called stellar wind paleontology. The fast-moving gas ejected at the end of the star's life must eventually catch up to, and collide with, the slow wind material emitted earlier. When the fast wind hits the slow material, it pushes the slow gas outward, sweeping it up like snow ahead of a snowplow. A shock wave forms at the head of this snowplow.

Shock waves are nature's version of traffic pile-ups. When drivers on a highway don't have time to brake smoothly, they slam into other cars in a noisy crunch of steel and glass. The same thing happens as the gas in the fast wind overtakes the slower moving material. Instead of noise, it is photons that emerge from the winds collision. The violence inherent to the shock wave heats the swept-up gas, which in turn produces light. Soon a brightly glowing shell is formed, a planetary nebula. From Earth these swept-up shells look like luminescent bubbles: bright rims of gas surrounding a darkened cavity with a dying star at the center.



Guillermo Garcia-Segura (Universidad Nacional Autonoma de Mexico)

Supercomputer models using the wind-blown bubble theory accurately reproduce Eta Carinae's Homunculus Nebula (right).



Jeff Hester (Arizona State University) and NASA

Variations on a theme, part 2: Hubble imaged the supermassive star Eta Carinae and its surrounding Homunculus Nebula.

Reading the Bones

Just as a fossilized footprint reveals volumes of information about the long-extinct dinosaur, a wealth of information about the star's evolution is encoded in the shape and structure of its wind-blown bubble. By learning to decode the language locked in the glowing bubbles, astronomers have found a way to reconstruct the history of the stellar winds. From there it is a short step to reach the heart of their concern; the dying central star.

Using this paleontological analogy, astronomers have been able to move through the catalog of planetary nebulae in an expanding circle of understanding. On one hand, the presence of the different wind phases explains why planetary nebulae exist at all. Knowing this, the properties of each nebula can be used to infer critical features of the star's evolution. A particular planetary nebulae bubble can, for instance, be decoded to reveal the duration of each wind phase, the different wind speeds, and even the amount of mass in each wind. Together these facts allow astronomers to reconstruct the dying years of these stars.

This is a ground-based telescope image of Eta Carinae and its Homunculus Nebula. But it was the Hubble Space Telescope that revealed the nebula's detailed structure (above).

Anglo-Australian Observatory/Photography by David Malin

One of the most important pieces of information locked in the planetary nebulae bubbles can be read from their shapes. If the slow and fast winds are kicked off the star with perfect spherical symmetry, then the resulting bubble will be spherical too. Even though some of the most beloved planetary nebulae are round, such as the Ring Nebula, round planetaries constitute only 20 percent of the total. In the mid-1980s, Bruce Balick of the University of Washington suggested that bipolar planetary nebulae would form if the slow wind was somehow kicked off the star with more mass expelled along the star's equator than along its poles, giving the slow wind a kind of extended doughnut shape.

When the fast wind rushing off the dying star encounters the gaseous doughnut, it pushes out quickly along the poles, where there is less matter impeding its progress. With the rapid expansion above and below the doughnut, the wind-blown bubble soon becomes distorted into an ellipse rather than a sphere. With enough excess matter in the equator compared with the pole, the bubble shell will become further distorted into two lobes aligned along the poles, producing a genuine hourglass-shape bipolar nebula.

Balick's model has proven to be extremely successful in accounting for the wide variety of planetary nebula shapes. Because planetary nebulae are bright and numerous, they have become a proving ground for the paleontology paradigm. Having successfully tackled the domain of the planetaries, this idea is now being extended to the seemingly endless variety of bipolar nebulae that surround other classes of elderly stars.

Eta Carinae and Its Little Man

While low- and intermediate-mass stars end their lives as planetary nebulae, massive stars always die in the apocalypse of a supernova explosion. One of the most extraordinary astronomical surprises of the last few years however is the realization that before they meet their fiery end, these massive stars also produce spectacular bipolar bubbles.

In 1837 a dim star in the Southern Hemisphere unexpectedly flared to life and remained the second brightest star in the night sky — outshined only by Sirius — for more than 20 years. Astronomers now recognize that star, known as Eta Carinae, as a member of a broader class of stars known as Luminous Blue Variables or LBVs. LBVs are hot, massive stars that for unknown reasons act like geysers, experiencing periodic eruptions (see "Star on the Brink," January 1997).

Eta Carinae is the most massive of all known LBVs, weighing in at a whopping 100 to 150 times the mass of the Sun. Throughout the 20th century, astronomers observing the region around Eta Carinae were puzzled by a dark rectangular-shaped cloud surrounding the star. Since it vaguely resembled a human form, astronomers named it the "Homunculus," which means "little man." When the power of the Hubble Space Telescope was turned on the massive star, however, astronomers quickly found that there was nothing diminutive about its Homunculus.

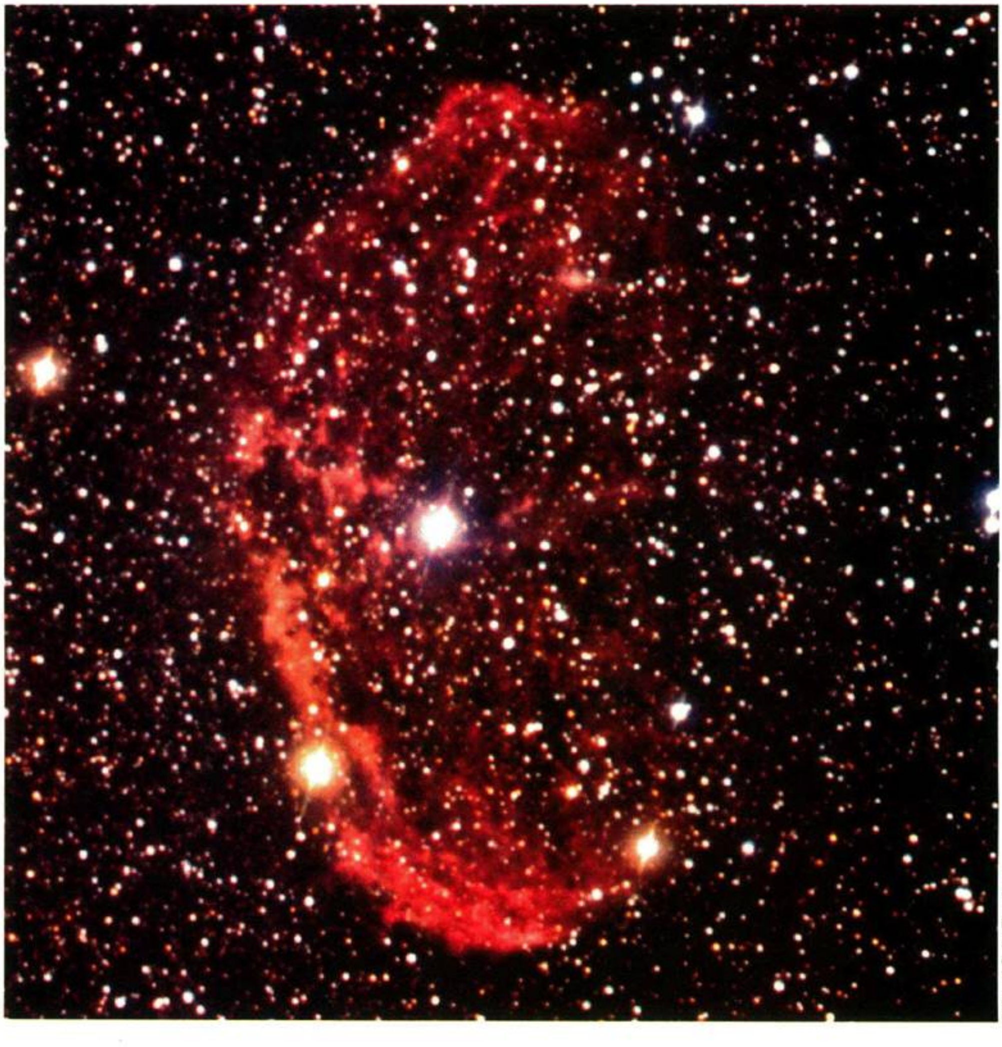
Instead of a little man, Hubble's stunning images revealed a bipolar nebula surrounding Eta Carinae, which appears to have two almost spherical lobes. The lobes are mottled like heads of cauliflower. Between the two lobes is what appears to be a thin disk of gas. Mysterious jets or rays jut out radially from the center of the disk. Taken together, these features make the images of Eta Carinae's Homunculus some of the most striking that the Hubble Space Telescope has produced.

Like the star it surrounds, the bipolar Homunculus is extreme in every way. Astronomers estimate that the Homunculus contains almost two times the mass of the Sun and that these massive lobes are expanding at almost 2.5 million kilometers per hour.

The presence of the disk and the bipolar lobes makes the Homunculus a perfect candidate for Balick's bipolar wind-blown bubble model and the stellar wind paleontology perspective. Just as in planetary

Anglo-Australian Observatory/Photography by David Malin

Variations on a theme, part 3: The wind-blown bubble model, originally developed to explain planetary nebulae, also works for bipolar nebulae surrounding Wolf-Rayet stars. The ultra-fast wind from Wolf-Rayet stars shreds their nebulae, giving rise to the tattered shapes seen in NGC 2359 (above) and NGC 6888 (below).



Bill and Sally Fletcher

nebulae, the bipolar lobes of the Homunculus could have formed as a fast wind from Eta Carinae slammed into the disk, blowing out the top and bottom of the gaseous Frisbee to form the spectacular bipolar lobes.

Astronomers know very little about how a star as massive as Eta Carinae should evolve. That, in turn, means they cannot know if the disk formed during or before the star's eruption. Perhaps the disk was even left over from the birth of the huge star. In spite of these uncertainties, they do feel confident that Eta Carinae's Homunculus is an example, perhaps even the best example, of a bipolar wind-blown bubble. Using the lessons learned from planetary nebulae, astronomers now hope to use the Homunculus to glean insights into the murky history of this extraordinary star.

Wolf-Rayet Stars and Their Ragged Bubbles

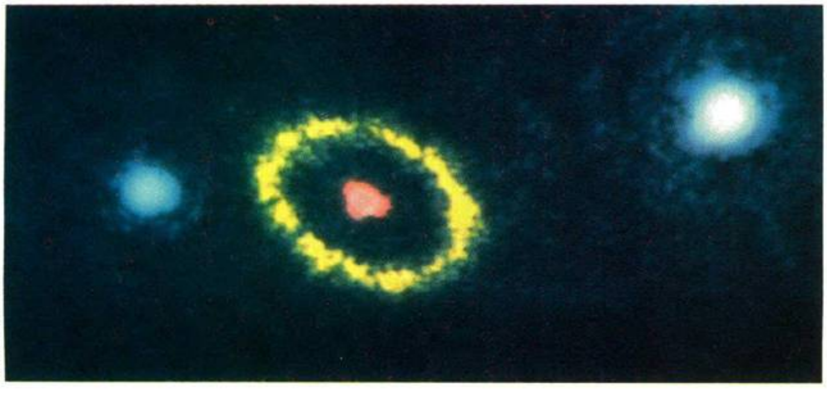
To scientists, nothing is more useful than a truly general theory. What makes stellar wind paleontology so powerful is its ever-widening sphere of applications. Another class of massive stars, known as Wolf-Rayets (pronounced *Rye-yay*), also possesses wind-blown bubbles. Like the LBVs, Wolf-Rayet stars are hot and drive strong winds into space. Astronomers believe that LBVs and Wolf-Rayet stars may form an evolutionary continuum whereby some Wolf-Rayets first become LBV's on their way to their eventual demise as supernovae. If this is true, then the fossil bubbles surrounding both kinds of stars may provide the critical information for mapping out the final years of supermassive stars.

The bubbles surrounding many Wolf-Rayet stars have a particularly striking attribute. The fast Wolf-Rayet winds are so powerful that when a wind-blown bubble forms, the swept-shells can become fragmented. When the Wolf-Rayet fast wind sweeps up the slow moving gas ahead of it, any bumps or lumps in the shell become amplified as the shell expands. At first the amplification of the irregularities produces small ripples on the surface of the shell. But these ripples are unstable and soon grow to the point where they begin to shred the shell, breaking it up into a semi-organized nest of filaments and gaseous fingers.

Recently, Guillermo Garcia-Segura and Mordecai-Mark Mac Low of the University of Illinois used powerful supercomputer simulations to show how the bipolar Wolf-Rayet bubble NGC 6888 (the Crescent Nebula), which has a particularly shredded shell, might have formed. In their simulations, Garcia-Segura and Mac Low drove a fast Wolf-Rayet wind into a mildly doughnut-shaped slow dense wind. Just as expected, instabilities formed in their simulated nebula, producing a model that beautifully matched the real shape of NGC 6888's shell — filaments, fingers, and all.

If these instabilities can shred the shells of Wolf-Rayet bubbles, then it is likely they might produce the mottled ripples on the surface of Eta Carinae's Homunculus as well. Understanding the formation of the instabilities is thus another aspect of stellar wind paleontology. The fragmentation of the bipolar shells only occurs if stellar winds evolve in a particular way. The presence, size, and shape of the shell filaments are all additional features of the gaseous fossils that can be used to understand the history of dying stars.

Thousands of years before it exploded, the progenitor star of Supernova 1987A gave off a dense wind of gas along its equator, forming a ring. When the supernova's shock wave ran into the ring, it lit up. This was one of the first Hubble Space Telescope images taken after its 1990 launch.



NASA and ESA

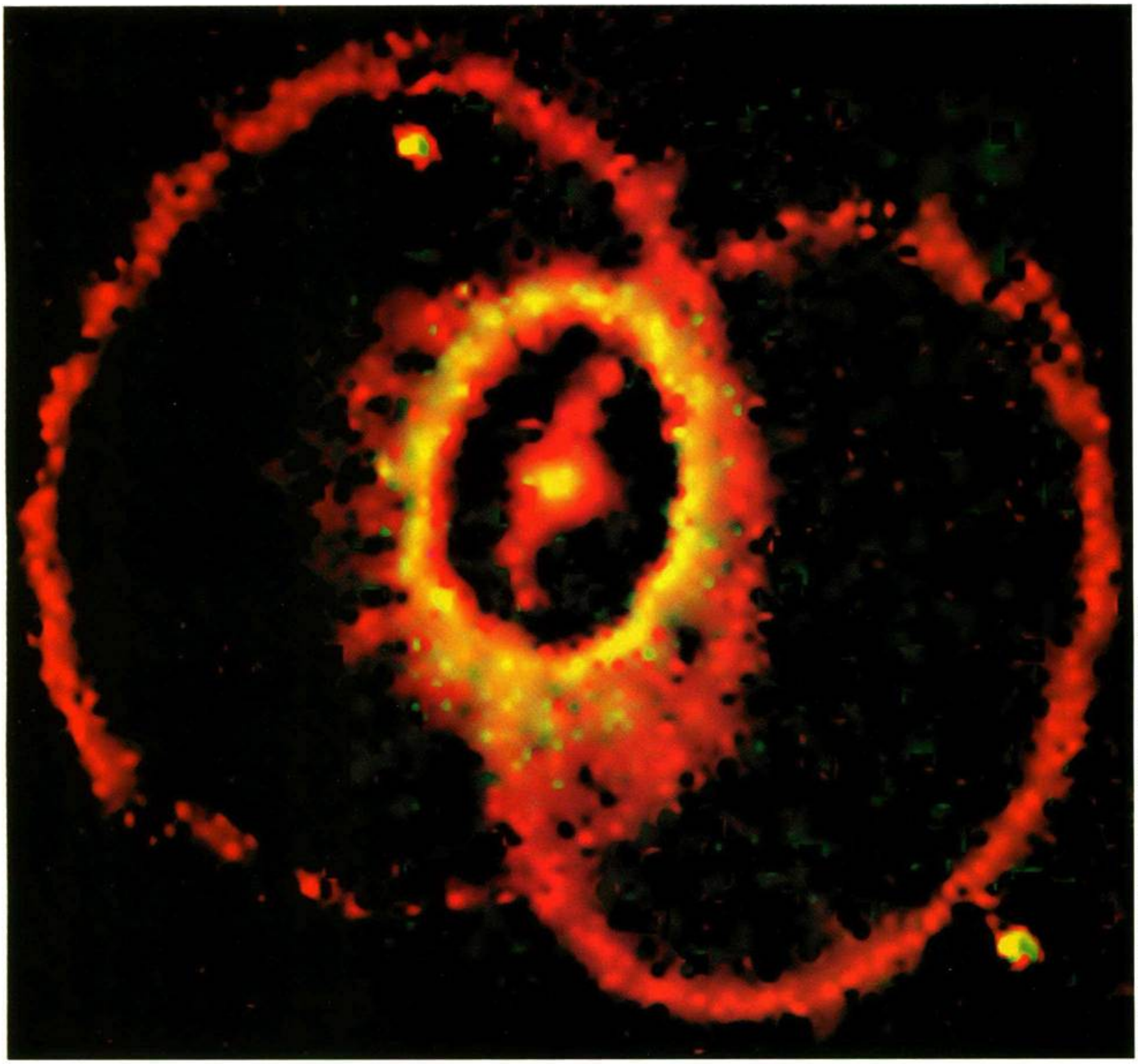
The Rings of Truth: Supernova 1987A

A particularly startling example of a bipolar nebula comes from an unexpected quarter of the universe: Supernova 1987A, which exploded ten years ago this month. The first Hubble images of Supernova 1987A, taken in 1990, revealed a bright ring of gas surrounding the spot where the star used to be. Within a year of the first Hubble images, three separate papers were published demonstrating that the central ring could be interpreted as part of a bipolar nebula.

In all forms of bipolar wind-blown bubble theory, the densest part of the slow wind occurs in the mid- or equatorial-plane of the dying star. The densest parts of the resulting shell are also the parts that glow the brightest. This model works out nicely for Supernova 1987A, since a star evolving through both a slow and fast wind phase before exploding should produce a bipolar bubble, which would appear to us as a ring.

Such bubbles may be quite common. In the last 10 years, astronomers have found direct evidence that supernovae occur in denser environments than normal interstellar space. Extra material probably comes from stellar winds that were driven off during earlier evolutionary epochs, including both the Wolf-Rayet and Luminous Blue Variable phases.

Newer Hubble images of Supernova 1987A have revealed the presence of not one but three rings. The two new rings are wider, fainter circles of light above and below the bright central ring. Projected on the sky, these three



Chris Burrows, John Krist (Space Telescope Science Institute), and NASA

Variations on a theme, part 4: This more recent Hubble photo shows the same ring surrounding Supernova 1987A, and two fainter rings. The rings are almost certainly the result of a bipolar wind-blown bubble.

rings appear as links in a chain of light. While there still is considerable debate about the exact nature of these additional rings, most astronomers agree that they are, somehow, connected with the upper and lower lobes of a bipolar bubble.

One Answer, Another Question

As more bipolar nebulae are discovered, their successful use as stellar wind fossils will continue helping astronomers chart the hidden histories of the central stars. Still, for all its success, the stellar wind model of bipolar bubbles leaves one pivotal question unanswered. To make a bipolar nebula, at least one wind phase must emerge from the star with an aspherical- or doughnut-shaped distribution. What produces such aspherical stellar winds?

The bipolar wind-blown bubble theory is mute on this point. It simply assumes such a wind exists and goes on from there. The origin of the doughnut-shaped winds is the next great frontier in understanding bipolar nebulae. Perhaps the aspherical winds are a consequence of a binary companion. Maybe the rotation of the star or magnetic fields are important. As of now, no one knows the answer. It's a secret still locked in the fossils.

That is, however, no cause for despair. It's just how science works. For every question answered, a new question emerges. Bipolar nebulae have been good to astronomers, providing them with a gallery of stunning images and a wealth of new information about stellar evolution. It is interesting to recall that philosophers have spent a lot of time wondering about the relationship between truth and beauty. Perhaps someone should tell them about bipolar nebulae. ☐

University of Rochester astrophysicist Adam Frank models the formation of bipolar nebulae on supercomputers. He wrote about rivers of galaxies in the August 1996 issue.

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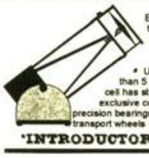

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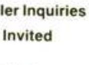

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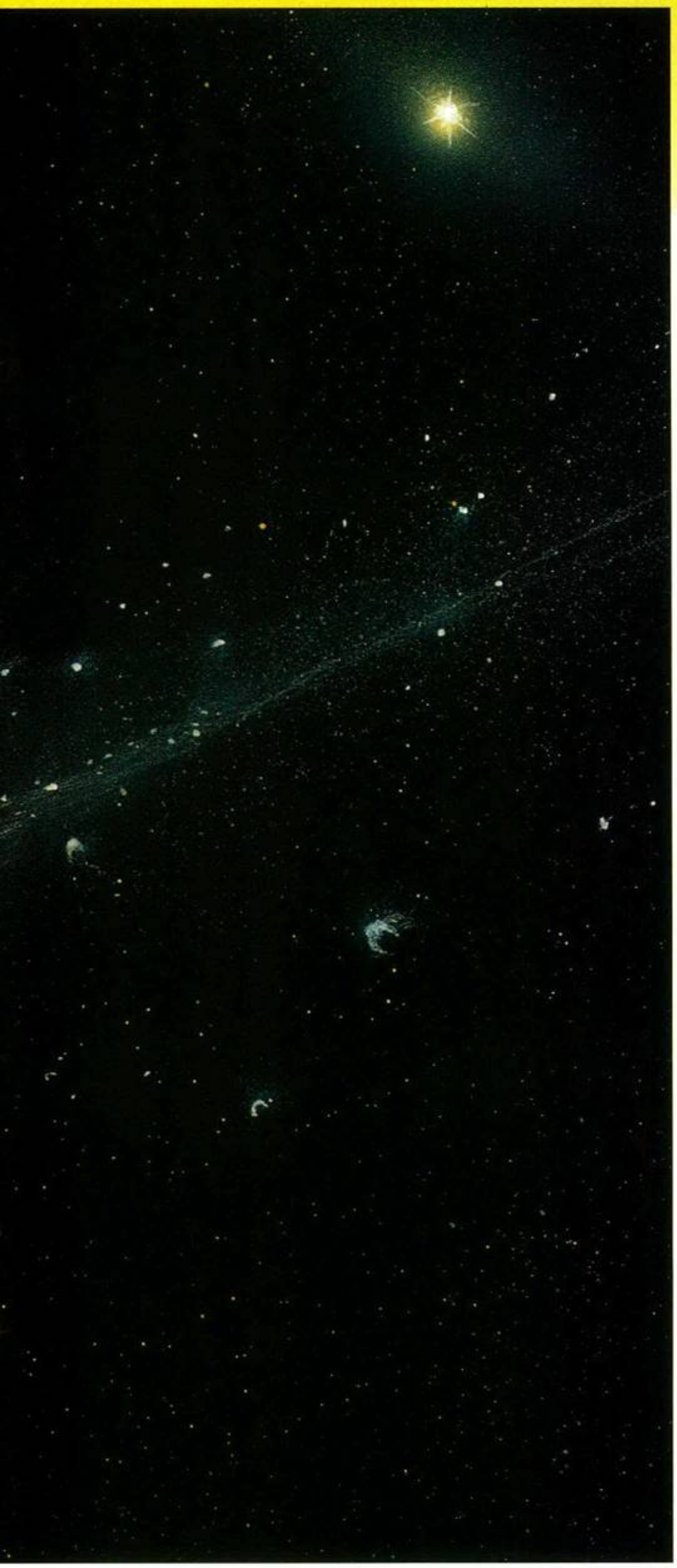


Bob Eggleton

We know interstellar comets exist, but astronomers have never seen one — yet.

by S. Alan Stern

Remember those old, silent Keystone Cops movies of a busy 1920s downtown intersection, brimming with cars, kids, cops, and robbers, but without a single traffic light in sight? Confusion abounded. Collisions were common. Chaos reigned. That's the image that comes to mind when I picture our solar system's early days, 4.5 billion years ago.

Over the past 40 years, careful studies of meteorites, lunar samples, and planetary surfaces, along with increasingly sophisticated computer models, have led the planetary science community to converge on a fairly consistent picture of how planets are built. And the truth is it's an inefficient and messy business.

The process tosses tremendous amounts of debris out of the solar system into the galactic disk, including trillions of comets. If solar systems like ours are common, then with billions of stars ejecting trillions of comets into the Galaxy, there must be huge numbers of comets roaming interstellar space.

In the shell of space between here and Alpha Centauri — the nearest star system — there may be as many as 50 trillion rogue comets, ejected from as many as 100 billion galactic planetary systems, each silently coursing its way through eons of interstellar night. Stored at temperatures only a few degrees above absolute zero, these comets contain a treasure trove of information about the formation of planetary systems across the Milky Way. The effort to find these denizens of deep interstellar space could begin before the decade is out.

Throwing Their Weight Around

One of the most interesting phases of planet building comes late in the game. Protoplanets larger than Earth have already formed. At this size, they begin to throw their weight (OK, actually their mass) around, their gravity begins to significantly stir the paths of objects in nearby orbits. This process is called gravitational scattering, and it has two profound effects. First, it increases the growth rate of the protoplanets,

When Oort Clouds Mingle: An Interstellar Comet Shower

Comets roam interstellar space unattached to other stars. However, comets don't have to be free of their parent stars to pass through our solar system. Oort Clouds, the shells of comets that surround stars, can intermingle.

Oort Clouds can be pictured as little bubbles in space, full of comets, with a diameter of roughly 20,000 AU, about ⅓ of a light-year. Whenever two stars with Oort Clouds pass within 20,000 AU of each other, their comet clouds temporarily intersect. Such encounters last about 3,000 years on average.

If half the stars in the Milky Way have Oort Clouds like our own, then about 500 encounters with foreign Oort Clouds have occurred over the age of the solar system. That's about one every 10 million years, on average. Of course, Oort Clouds may not exist around half of all stars, so these kinds of events could be much rarer. But if even one star in 1,000 has an Oort Cloud, then our solar system should have seen at least one comet shower from another sun.

During each encounter, up to 1,000 comets from the intruder Oort Cloud could be passing within 10 AU of the Sun at any given time, about 30 of which would be close enough to exhibit tails. Amateur astronomers would walk around like insomniacs from staying up late and looking at 30 comets every night. The odds of Earth being hit by any of these comets, however, are minuscule; only about one comet should hit Earth for every 300 intruder Oort Clouds that pass through our solar system.

because the rate at which they collide with smaller bodies increases. Second, it also begins to dramatically affect the orbits of bodies coming close to, but not colliding with these objects.

It's just this action that generates the Keystone Cops scenes. As you can imagine, small bodies, ranging in size from rocks to Manhattans, become corks adrift in a rather rough sea. With many protoplanets growing at once, these small bodies become billiard balls careening among the protoplanets.

In the shell of space between here and Alpha Centauri there may be as many as 50 trillion interstellar rogue comets.

In the case of giant planets like Jupiter and Saturn, their gravitational effects are so strong that objects passing near them are frequently ejected into interstellar space. (This still occasionally happens today when a comet comes close to one of these behemoths). Of course, not all objects are ejected. Some, like Comet Shoemaker-Levy 9, actually do strike planets and help them grow. Others are scattered inward, closer to the Sun, where it's much harder for them to escape. Still others are not ejected because they don't quite get enough boost; these planetesimals end up in long, lonely orbits that can reach to distances as great as tens of thousands of astronomical units (AU) from the Sun. This process is the one that populated the Sun's Oort Cloud with the icy planetesimals we call comets.

Scott Tremaine of the Canadian Institute for Theoretical Astronomy has recently shown that Jupiter and Saturn were so massive they tended to eject most of the planetesimals that came close to them. However, he also found that less massive Uranus and Neptune threw a much greater fraction of the planetesimals in their region of the solar system into the Oort Cloud, rather than onto one-way trips to galactic exile.

Other studies, by Wing Ip of the Max-Planck-Institute in Germany and Julio Fernández of the University of Montevideo in Uruguay, indicate that Jupiter and Saturn probably ejected about 10 objects from the solar system for every one they scattered to the Oort Cloud. But Uranus and Neptune only ejected one object for every two or three they injected into the cloud. Overall, the process of building the giant planets in our solar system is estimated to have injected several trillion (i.e., up to 3x10^{12}) planetesimals into the Oort cloud, and between 10 and 100 trillion planetesimals into interstellar space. This planet-building stuff really is a messy business!

Put another way, our solar system alone ejected so many objects into the Galaxy that the number (but certainly not the mass) of comets in the Milky Way vastly exceeds the number of stars. If solar systems like our own are common, then this scenario has repeated itself billions of times, and the population of interstellar comets is impressive indeed.

Life in the Interstellar Outback

What is life like for interstellar comets? It isn't very exciting. They are subject to an eternal deep freeze that for all practical purposes puts them in permanent and very effective long-term cold storage.

The main heat sources are the cosmic microwave background (a 3° bath from the Big Bang) and plain old starlight from the dark interstellar sky. Together, these two feeble radiations aren't likely to warm comets much above 5° or 6° C above absolute zero. At these cryogenic temperatures, chemical reactions are so slow as to be effectively nonexistent, and none of the common cometary surface ices that turn into gas when heated in the planetary region, like water, carbon monoxide, nitrogen, and methane, show any activity. You might say deep interstellar space makes a very nice morgue, preserving our friendly comets for all eternity.

Well, not quite. Research in the last decade or so has revealed that a few types of very subtle changes can occur on the surfaces of interstellar comets. The first breakthrough came when Bob Johnson at the University of Virginia, Lou Lanzerotti of Bell Labs, and their co-workers showed that cosmic rays and ultraviolet radiation from distant stars will penetrate the upper surface layers to a depth of perhaps a meter or two, driving out lightweight volatile molecules and creating micro-flaws in ice crystals. These kinds of radiation damage may darken and perhaps redden the icy cometary surfaces over billions of years.

A few years later, work I did with Mike Shull of the University of Colorado showed that two other effects are also important. First, passing hot and massive O type and B type stars, and nearby supernovae explosions, will occasionally heat interstellar comets to comparatively balmy temperatures — perhaps 30° C above absolute zero (that's still about –440° F). At these very cold temperatures, which are ten times what interstellar comets normally experience, it's possible for noble gases and a few molecules like nitrogen and carbon monoxide to leak out of the surface layers.

More importantly, we also found that micro-impacts from smoke-sized interstellar grain particles will erode the surfaces of interstellar comets, perhaps removing their outer, radiation-damaged rind. But that's it. It's like the Middle Ages in Europe — only worse: *Time goes by, but nothing ever changes.*

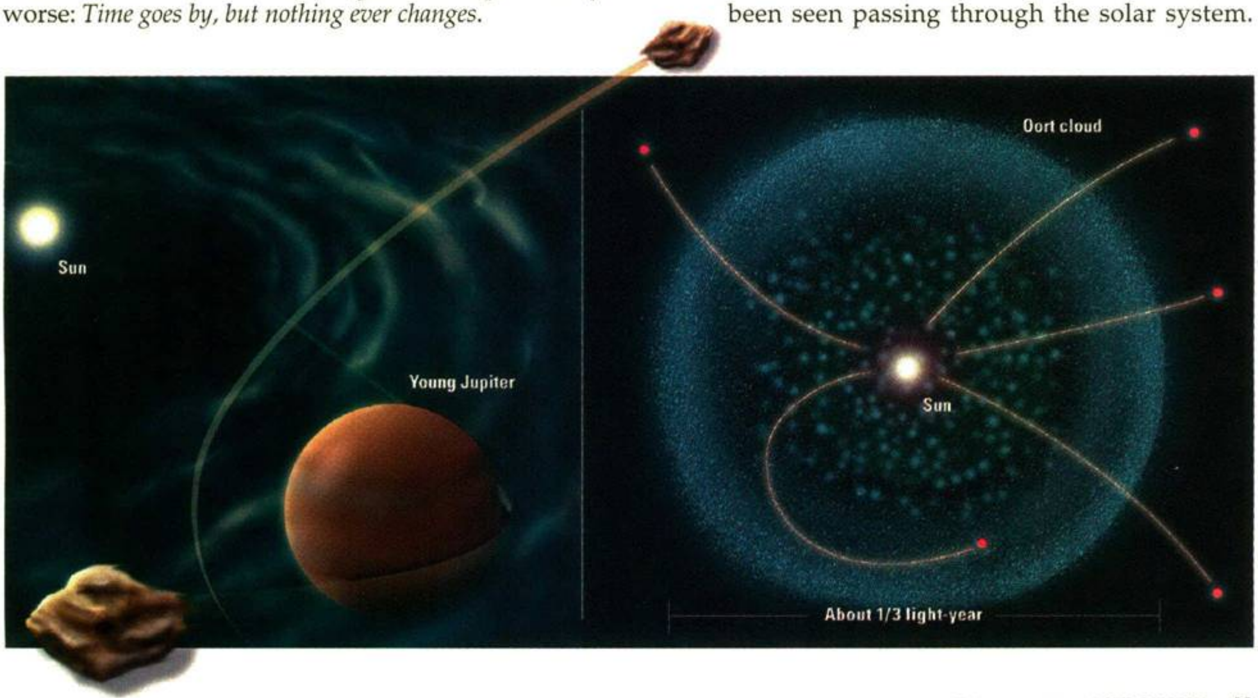
The Number of the Beasties

The wonderful thing about interstellar comets is that they are a direct product of giant planet formation. According to what we now know, if you form giant planets, you eject a lot of interstellar comets. The number of interstellar comets produced per solar system depends strongly on the spacing and masses of the giant planets, the mass of the disks from which the planets formed, the race between the rate at which giant planets form and begin to eject comets, and the length of time the disk-like planetary nebula retains its gas. Still, it's an exciting prospect to think that by measuring the population of nearby interstellar comets we can get information on the total number of solar systems in the Milky Way's disk that have giant planets.

Deep interstellar space makes a very nice morgue, preserving our friendly comets for all eternity.

But exactly how many interstellar comets should one expect in the Milky Way? There are two ways to get a rough handle on the size of this population. First, one could suppose all 200 billion stars in the Milky Way have formed Oort Clouds just like our own, each star ejecting some 30 trillion or so planetesimals. That would imply a population of roughly 6 X 10^{24} interstellar comets (that's 6 trillion trillion of the beasties, with a total mass of about 170 million Suns).

To get a second estimate on the number of comets, one can use the fact that no interstellar comet has ever been seen passing through the solar system.



ASTRONOMY: Phil Kirchmeier

This gives astronomers an upper limit on their concentration in space. From this, Zdenek Sekanina of the Jet Propulsion Lab calculated that on average, there is no more than one interstellar comet for every 1,500 cubic astronomical units of space near the Sun. We can use this number to crudely estimate the upper limit by multiplying the concentration of comets ($^1/_{1500}$, or 0.00068 per cubic AU) and the volume of the galaxy (about 200 billion cubic parsecs, or $1.5 \text{x} 10^{27}$ cubic AU), which gives one trillion trillion (10^{24}) comets.

It's surprising that these two estimates are in rough agreement. It means that the observational data don't tell us very much about the population of interstellar comets. As much as 20 percent of the stars in the Galaxy could have produced Jupiter- and Saturn-mass planets and we still wouldn't have run across an interstellar comet in our normal comet hunting.

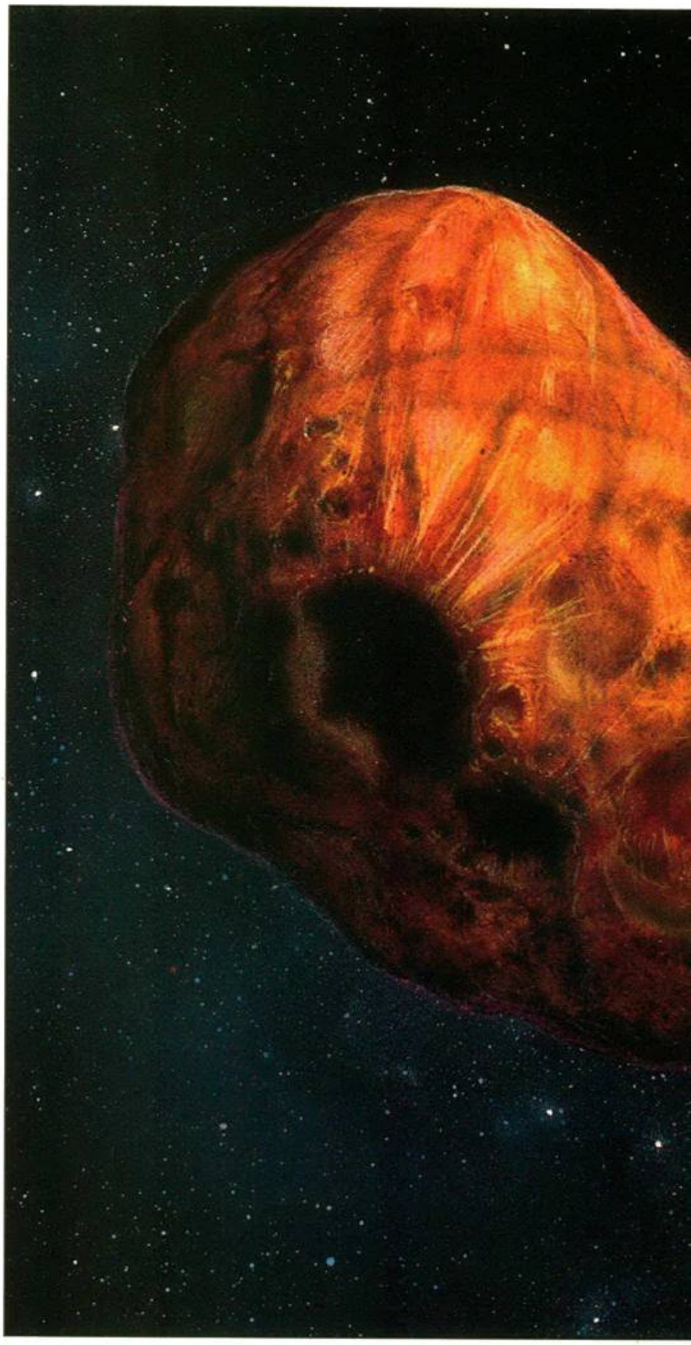
It could take 1,500 years at the present rate of comet discovery to find an interstellar comet.

But don't take that 20 percent number to the bank. Our solar system might have ejected an unusually large number of planetesimals, in which case the existing constraints on the interstellar comet population could be consistent with jovian planets around every star in the whole Galaxy. Simply put, we just don't know enough to know — we must go and look.

Visitors from Another Pond

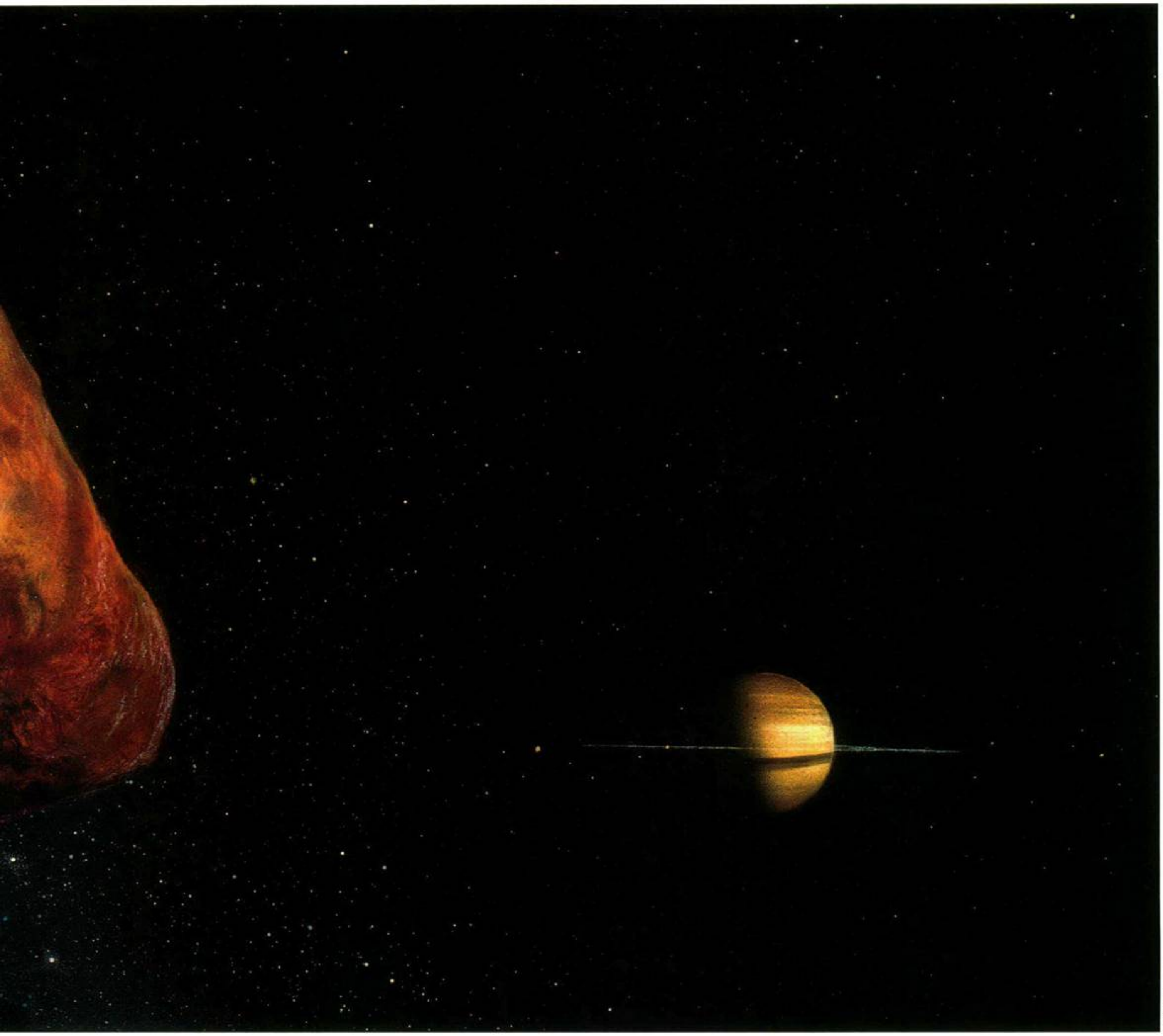
Interstellar comets would be easily distinguishable from solar system comets because they will pass through the solar system with, on average, the same speed that the Sun is making against the local stars. That's about 20 to 30 kilometers per second, compared to 10 km per second for comets from our own Oort Cloud. Because of their high velocity, interstellar comets follow a hyperbolic trajectory, unlike the parabolic trajectory coursed by solar system comets such as Hale-Bopp. The hyperbolic velocity of 20 to 30 kilometers per second would make an unmistakable John Hancock for interstellar comet confirmation.

Comet hunters regularly detect comets from our Oort Cloud, but after 250 years of comet hunting, no comet with a clearly interstellar orbit has been found. Tom McGlynn and Bob Chapman of NASA's Goddard Space Flight Center have estimated that it could take 1,500 years at the present rate of comet discovery to find an interstellar comet, or to prove they are rare. We can do far better if we try an active search.



How would one conduct a search for interstellar comets? With a little ingenuity. As noted earlier, the best upper limit on the space density of interstellar comets is about one per 1,500 cubic AU. That means that the mean distance between interstellar comets in the Milky Way could be as little as 11 AU. It might even be a little higher near the Sun, because the Sun's gravity will attract them toward our direction. That's about the distance from the Sun to Saturn, which means that at any time (such as now) there should be one interstellar comet somewhere in the shell of space around the Sun as defined by Saturn's orbit.

At a distance of 11 AU from the Sun a comet like Hale-Bopp would be inactive, and therefore would be a dark nucleus reflecting the diluted light of the distant Sun. As seen from Earth, it would have a visual magnitude between 22 and 25. This is faint, but not too faint to discourage us; most of the recently-discovered Kuiper Disk objects have magnitudes this faint.



Bob Eggleton

But where to search? Scouring the entire sky to 24th or 25th magnitude is a little much to ask. Fortunately we know something about where the needles are in this haystack. Interstellar comets will come from the apex of motion in the direction the Sun is moving in space, toward Hercules. It's a little like a meteor shower radiant, except for the fact that the so-called "meteors" are comets, and they will appear at the rate of perhaps one every few years. By searching a 1 degree-wide-strip about 45 degrees in radius centered on the apex of solar motion about once a week, one can ensure that no interstellar comet will slip by. Candidate objects can be followed up with subsequent observations after they pass through the detection strip in order to confirm whether or not they are in fact on hyperbolic trajectories from interstellar space.

With a search strategy like this, astronomers could double the present-day interstellar comet detection limit after about 18 months. After 10 years, a ten-fold improvement could be achieved. By that time, it's possible, maybe even probable, that a real, bona fide interstellar would have been bagged, giving us not only a chance to study a comet from another solar system, but also some solid evidence about the galaxy-wide frequency of solar systems with giant planets like our own. □

Planetary astronomer S. Alan Stern directs the Southwest Research Institute's Geophysical, Astrophysical, & Planetary Sciences research group in Boulder, Colorado. He wrote "Wish Upon a Star" in the December 1996 issue.

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8'' f/6

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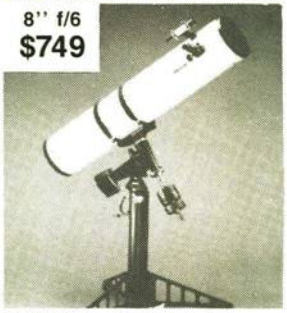


New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

6'' f/8 **Dobsonian Starfinder** ($46 P&S)	**$319**
6'' f/8 **Equat. Starfinder 6**(add $79 P&S) ...	**$649**
8'' f/6 **Dobsonian Starfinder** (add $59 P&S) .	**$419**
8'' f/6 **Equat. Starfinder 8** (add $89 P&S) ...	**$749**
10'' f/4.5 **Dobsonian Starfinder** ($85 P&S) ..	**$599**
10'' f/4.5 **Equat. Starfinder 10** (add $99 P&S)	**$879**
12.5'' f/4.8 **Dobsonian Starfinder** ($95 P&S)	**$895**
16'' f/4.5 **Dobsonian Starfinder** (freight COD)	**$1195**
16'' f/4.5 **Starfinder 16** (ship. freight COD) .	**$2695**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector .	**$99**
Magellan computer; specify Dob. or Eq. ($15 ship)	**$295**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination ..	**$475**

SKY VECTOR™ $299!!

Includes Computer, Encoders, Hardware

LUMICON ACCESSORIES

LUMICON, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LOW PRICE—from $299

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $299

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $349

10,000 Objects! — Also includes Identify (Sky Tour) Function, planets and full visual descriptions.

NGC SKY VECTOR™ $439

12,000 Objects!— PC Serial Port

NGC-Sky Vector
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON

NGC SKY VECTOR with IDENTIFY (Sky Tour) mode, 12,000 object memory including the corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth, Meade 6-16'' Dobsonian.
Ultima 8, 9¼, 11 **add $25**, C-14 **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER .	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7 ...	**$129.00**
2'' Adapter for Hasselblad .	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing ...	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS
New! Thread-on for Odyssey

FROM $69.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape!
Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
LUMICON 2'' Helical Focuser 1½'' high	**$75.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2'' Astro Systems focuser, only 2'' high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$189.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, 45°version	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER .	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER ..	**$199.50**
1¼'' right-angle version, w/star diagonal ..	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$59.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc. ..	**$29.50**
2'' adapter for C-80, C-100 refractor ...	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1'' long 1¼'' OD thread-in extension ...	**12.00**
2½'' long extension (holds 1¼'' filters) .	**19.50**
4½'' long extension for 1¼'' eyepieces	**$29.00**
3'' long extension for 2'' eyepieces* ..	**$29.00**
2'' long extension for 2'' eyepieces* ..	**$29.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing,threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

Meade & Celestron
LUMICON carries a full line of telescopes and accessories. Fast Delivery. Competitive Prices.

LUMICON FOR HIGH PERFORMANCE

Visit our LUMICON web-site: http://www.rahul.net/Astro-Mall

NEW LUMICON MULTIPLE FILTER SELECTOR

$129

ALWAYS GET THE BEST VIEW!

$99
(If ordered with filter or filter set)

The New LUMICON Multiple Filter Selector holds up to 5 1¼" LUMICON filters. The sliding bar has a click-stop at each filter position. Now you can instantly select the best filter for any deep-sky object. Cost is $129 or $185 with 1.5X relay lens (for Newtonians). **Save $30 if ordered with filter(s)!**

TELE VUE™

NEW! Bino Vue Binocular Viewer

Genesis-SDF 4" f/5.4 apochromat	$1950
Pronto 70mm f/6.4 apochromat w/2" diagonal	$939
Pronto 70mm f/6.4 w/45° erecting prism	$789
NEW! Bino Vue binocular viewer	$899
Gibraltar mount with ash wood tripod	$495
10.4, 26mm Plossl 50°	$79
8, 11, 15mm Plossl **$89**, 20, 25mm	$99
32mm Plossl, widest true field in 1¼"	$119
55mm 2" Plossl, widest possible field	$229
2.0x or 3.0x Tele Vue Barlow Lens	$115
2" Giant Barlow - 2x	$179
15mm Wide-Field, 1¼" eyepiece, 65°	$139
4.8mm Nagler, 82° field, 1¼" eyepiece	$169
7mm Nagler, 1¼" eyepiece, 82° field	$219
9mm Nagler, 82° field, 1¼" or 2"	$239
13mm Nagler, 82° field, 1¼" or 2"	$299
12mm Nagler, Type II, 82°, 1¼"/2"	$279
16mm Nagler, Type II, 82°, 1¼"/2"	$299
20mm Nagler, Type II, 82°, 2" only	$375
2" Paracorr Visual Coma Corrector	$249
15mm Panoptic 1¼", 68° field	$209
19mm Panoptic 1¼", 68° field	$245
22mm Panoptic 1¼"/2", 68°	$269
27mm Panoptic 2", 68° field	$319
35mm Panoptic 2", 68° field	$349

TeleVue Warranty may not be valid outside USA.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$189.50**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON O-III proved to be our favorite... It gave the greatest contrast gain." *ASTRONOMY*, February 1991

AMAZING O-III FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

GREATLY ENHANCED DETAIL

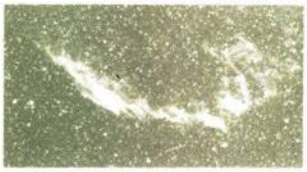
"Consistently performed well on all emission and planetary nebulae. Detail and structure were greatly enhanced in the more than two dozen objects I viewed." ***SKY & TELESCOPE*, July 1995**

BETTER THAN A DARK-SKY SITE!?

"From my light polluted backyard, the view ... was better with the O-III than with any other filter tested. The view was even better than without the filter from a dark-sky site." ***SKY & TELESCOPE*, July 1995**

SEE THE HORSEHEAD!

*"**LUMICON's H-Beta Filter** will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae. . ."* ***SKY & TELESCOPE*, July 1995**



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."* ***ASTRONOMY*, February 1991**

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$199.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$199.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	$399.50
2" Rear Cell Filter, fits SCT's Deep-Sky, **$199.50** UHC, O-III, H-Beta,	$199.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
Choice of ***any two*** LUMICON filters (**Save 7%**) 1¼" **$185.00**; 48mm	$370.00
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼" $99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines 1¼" **$99.50; 48mm**	$199.50
LUMICON Comet (Swan band) Filter 1¼" **$99.50; 48mm**	$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$7.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$19.50
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$25.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the LUMICON Deep-Sky (DS) Filter.

Specify Lens Size	H-Alpha	(DS)
46, 48, 49mm	$59.00	$199.50
52, 55, 58, 62mm	$69.00	$199.50
67, 72, 77mm	$79.00	$399.50
82mm (77mm + adapter)	$89.00	$415.00

Hypered 2415 film, 36 exp **$11.95, $3/$32**

LUMICON®

2111 Research Dr. #5A, Livermore, CA 94550
For phone orders please call (510) 447-9570
FAX (6 PM-9 AM PST) (510) 447-9589
LUMICON Products catalogue FREE
All foreign orders add 8% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 9 am - 1 pm

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10-12" Meade. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** ... **$109.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, pulsed.

2. **Cable release** for long exposures . **$9.95**

3. **Declination motor** (state telescope type) **$109**

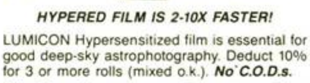
4. **Dual-axis drive corrector** for telescope. This should be part of the telescope when purchased. Call LUMICON for details.

5. **LUMICON EASY-GUIDER** (selection to left)

6. **LUMICON 48mm DEEP-SKY FILTER $199.50**
This is essential for highest possible contrast. Contrast is boosted up to 3X for ***both*** color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.

7. **Hypersensitized film.** Purchase from LUMICON or make your own with a LUMICON HYPER-KIT.

TRY PPF! HYPERSENSITIZED FILM



HYPERED FILM IS 2-10X FASTER!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	Exposures	Price
Kodak PPF-400, THE BEST!	36	$14.95
2415, Ultra-fine B&W, red sens.	36	$11.95
SR-G3200, fastest of all, color neg	24	$13.95
Kodak Gold 1000 fast, fine grain	12	$13.95
Fuji G800 fine grain color neg.	24	$13.95
Ektachrome 1600, fast slide film	24	$14.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

Toward a New

Hubble

Expect new and better things from the Space Telescope after astronauts outfit it for the '90s.

by John Shibley and Richard Talcott

Who can forget the excitement of December 1993? NASA's reputation was on the line as a crew of seven astronauts rendezvoused with the Hubble Space Telescope, replacing faulty guidance systems and solar arrays and, most important, installing a corrective optics package to improve the telescope's blurry vision.

Well, as anyone who has seen the spectacularly crisp images returned by Hubble can tell, the mission was an unqualified success. The telescope now meets its original design criteria, routinely achieving a resolution of 0.1 arcsecond. Results from Hubble have allowed astronomers to monitor the outer planets (including Comet Shoemaker-Levy 9's historic collision with Jupiter in 1994), probe the nuclei of active galaxies, study galaxy formation and evolution in the distant universe, and determine more accurately the size and age of the cosmos.

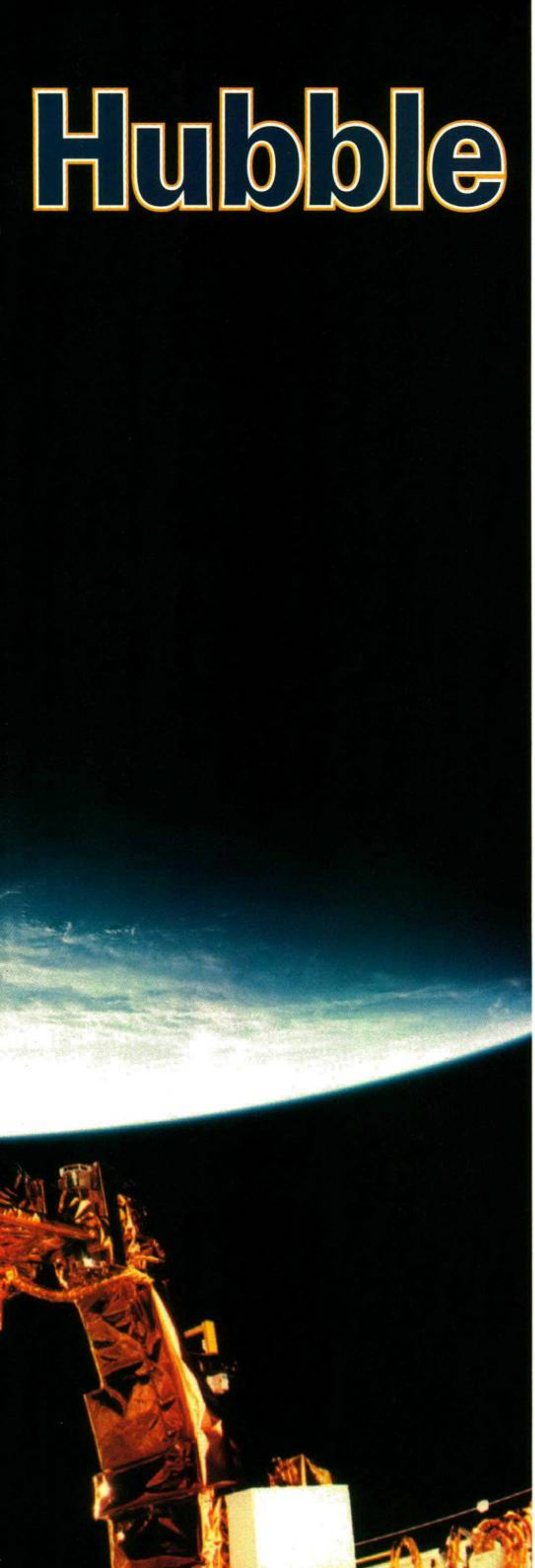
Now, NASA is preparing to head back to Hubble. Why risk messing with a perfectly good observatory? Hubble was designed so that astronauts could return every few years to perform routine maintenance and update the telescope's technology. It currently runs on technology dating from the 1970s. The goal is to bring it up to the 1990s, or at least to the late 1980s.

Two New Instruments

The top priorities for the mission, scheduled for launch on February 13, 1997, are to install the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) and the Space Telescope Imaging Spectrograph (STIS). NICMOS will replace the Faint Object Spectrograph and STIS the Goddard High Resolution Spectrograph. The Wide Field/Planetary Camera 2 and Faint Object Camera (the only scientific instrument remaining of the original five) will remain.

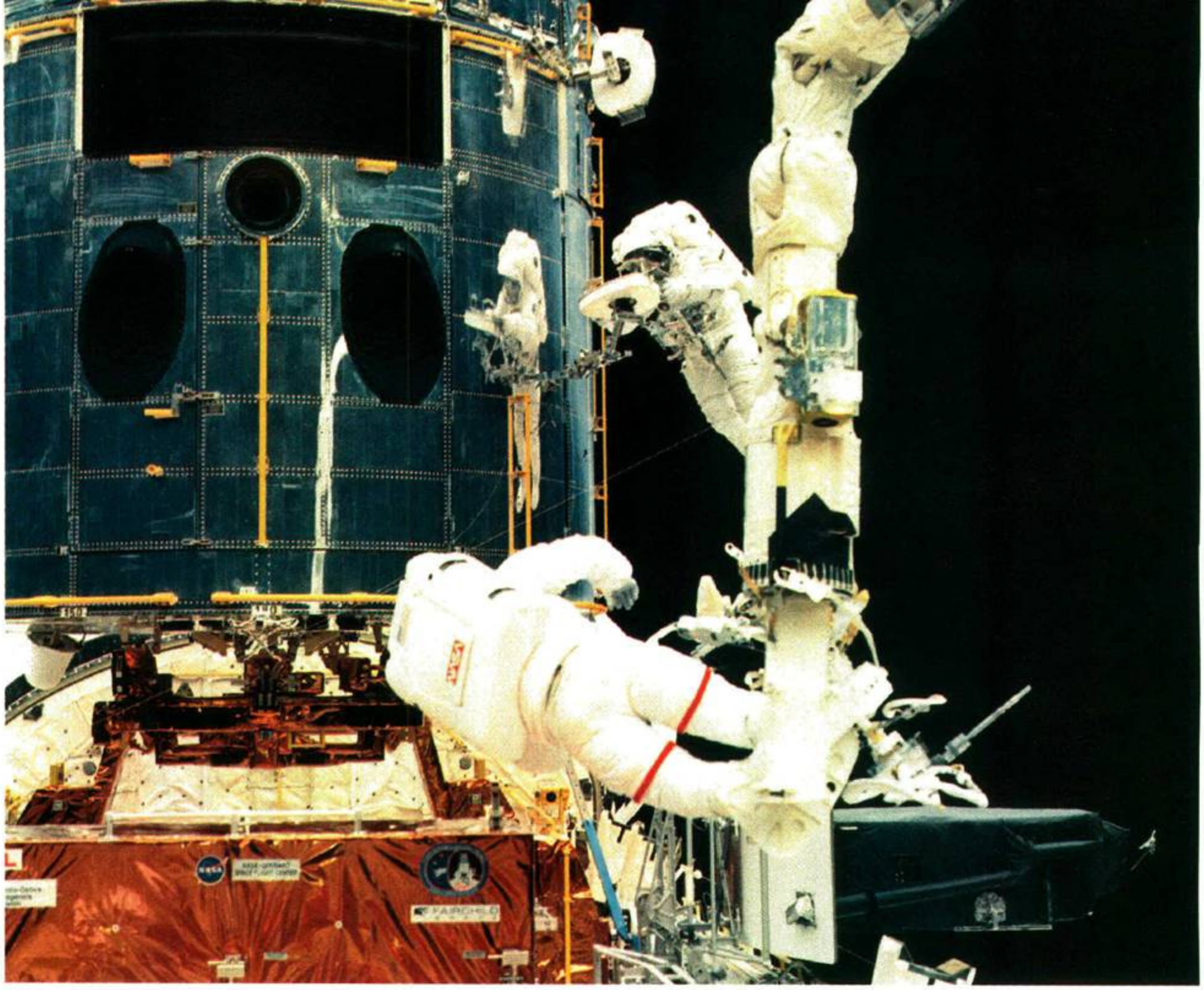
NICMOS observes at near-infrared wavelengths, from 0.8 to 2.5 micrometers, just a little longer than those of visible light. Because water vapor in Earth's atmosphere blocks most near-infrared radiation coming from the cosmos, NICMOS promises results difficult or impossible to get from the ground. HST — in its high, dry orbit — will see all this radiation, and at a far higher resolution than ever before. Astronomers plan to use NICMOS to study protoplanetary disks around stars, probe the dusty cores of active galaxies and, perhaps most significant, image young galaxies in the far reaches of the universe.

NICMOS will accomplish this using three cameras, each working at a different magnification. The cameras operate simultaneously but separately, so filters and exposure times can be different on each, and view



NASA

The last time we saw HST up close, it was drifting away from the shuttle after NASA's first servicing mission in December 1993.



NASA

Astronauts busy themselves during the December 1993 servicing mission. The large rectangular opening is where the Wide Field/ Planetary Camera 2 was installed.

Servicing Hubble

Extravehicular activity #1

0:00-1:00	Set up
1:00-3:00	Remove Goddard High Resolution Spectrograph Install STIS
3:00-5:00	Remove Faint Object Spectrograph Install NICMOS
5:00-5:30	Clean up

Extravehicular activity #2

0:00-0:15	Set up
0:15-2:45	Replace Fine Guidance Sensor
2:45-3:35	Install optical control electronics
3:35-5:00	Remove tape recorder
5:00-5:30	Clean up

Extravehicular activity #3

0:00-0:15	Set up
0:15-2:15	Replace Data Interface Unit
2:15-4:00	Install Solid State Recorder
4:00-4:30	Clean up

Extravehicular activity #4

0:00-0:15	Set up
0:15-2:20	Replace solar array drive electronics
2:20-3:15	Install cover for magnetic sensors
3:15-4:15	Clean up

adjacent though not contiguous fields. Two of the three cameras will yield images at the theoretical limit of the telescope's optics. One contains a 0.63-arcsecond-diameter occulting disk, which allows astronomers to block out the bright center of an object and observe details in fainter, outlying regions. The widest field camera will take spectra of many objects at the same time.

With both of the current spectrographs being removed during the servicing mission, STIS will become the only spectrograph on board Hubble. It should more than compensate. STIS will observe in four spectral bands extending from the ultraviolet at 115 nanometers to the near infrared at 1000 nanometers (1 micrometer), exceeding the range of both of its predecessors. And its two-dimensional detectors will also far exceed the capabilities of its predecessors' linear detectors.

STIS should produce a scientific bonanza. The high-quality spectra it returns will allow astronomers to study the dynamics of nearby galactic nuclei, star formation and evolution, the composition of the interstellar medium, and the planets and their moons.

And That's Not All

Even without swapping in NICMOS and STIS, the astronauts would have a busy schedule in space. They will also install a new Solid State Recorder capable of storing ten times more data than the tape recorder it replaces. They'll swap in a refurbished Fine Guidance Sensor (FGS) used to point the telescope. (Hubble has six FGSs, of which three are needed to point the telescope. Because they have had a history of problems, NASA plans to replace one with each new servicing mission.) And they will install both a Data Interface Unit to help manage the flow of information from Hubble and new drive electronics for the solar arrays.

To carry out these tasks, NASA has selected seven astronauts who collectively have flown 15 space missions. Kenneth Bowersox, who piloted the shuttle Endeavour on the first servicing mission, will be mission commander on Discovery and Scott Horowitz will serve as pilot. Mission specialists include Steven Hawley, who will operate the robotic arm, and spacewalkers Mark Lee, Gregory Harbaugh, Steven Smith, Jr., and Joseph Tanner.

Before the shuttle links up with Hubble, ground controllers will have closed the telescope's aperture door to avoid contamination. And unlike the previous servicing call, the solar arrays will remain unfurled throughout the mission to prevent damage.

Once the astronauts grab HST with the robotic arm and place it in the shuttle's payload bay, they'll be ready to get to work. The heart of the ten-day mission will consist of four extravehicular activities, or EVAs. The timeline on the opposite page gives NASA's detailed plans. The schedule is preliminary, however, and could change either before the launch or based on the progress of the spacewalking astronauts.

Are there risks involved in the servicing mission? Any time the shuttle comes close to the Space Telescope or astronauts start removing or installing equipment, there has to be a little concern. But no signs of human contact could be seen following the first servicing mission and, on paper at least, this mission is simpler. The main peril is in complacency.

It will take a few months after the flight to verify that everything went well and that the new instruments are operating properly. But by late spring you can expect to see the results of the servicing mission and, if everything goes well, more stunning results.

Keep a Good Thing Going

The February servicing mission comes at almost the halfway point in Hubble's 15-year mission. NASA has scheduled two more servicing missions beyond this one to keep their $2 billion investment going.

The main goal of the 1999 mission will be to boost HST into a higher, more stable orbit. By then solar activity will be nearing a maximum, and the increased solar flux will cause Earth's outer atmosphere to expand, increasing drag on the telescope.

Once the space shuttle docks with and secures Hubble, astronauts will fire on-board thrusters to elevate HST's orbit at least 100 kilometers. The mission will also install fresh solar panels and an advanced camera that's ten times better than the cameras now onboard. Hubble will also receive a new computer, some fresh rechargeable batteries, and a refurbished Fine Guidance Sensor to better aim the telescope.

Son of Hubble Space Telescope?

Any Hubble servicing flights after the three scheduled through 2002 will be largely determined by whether NASA operates the telescope past 2005. The agency and its partners may want to pour money normally spent on HST management into a next-generation space telescope (NGST). NASA did something like this when it mothballed the Kuiper Airborne Observatory in 1995 to free up funding for the 747-housed Stratospheric Observatory for Infrared Astronomy. SOFIA is due to fly in 2000.

But a committee charged by NASA last year to chart out what should follow HST recommends funding the Hubble, equipment permitting, well beyond its 15-year nominal mission. This would tide astronomers over until the next-generation space telescope is launched and functional.

And what would the NGST be like?

First, the committee advises it be placed far from Earth at L2, an ultrastable point in space some 1,500,000 kilometers away where the Sun's and Earth's gravity balance exactly. Currently, Hubble must shoot around a looming Earth and stay clear of the planet's blinding glare.

Second, NGST should have a bigger primary mirror, up to 8 meters in diameter compared with Hubble's 2.4-meter mirror. The telescope should also be optimized for studies in the near-infrared. Among other things, this wavelength range lets astronomers peer through obscuring dust clouds and maybe even detect heat given off by Earthlike extrasolar planets. In addition, the telescope would employ a technology that hooks it up by radio with telescopes on Earth to create a virtual mirror as wide as NGST's orbit.

Third, NGST should use advanced technology to keep costs within a $500 million cap. Hubble's development costs swelled to over $2 billion for a variety of reasons. To avoid this, designers would use inflatable composite assemblies that launch on cheaper, expendable rocket boosters.

How soon might NGST launch? If NASA follows the committee's recommendations, it could go up as early as 2006, just one year after HST wraps up its nominal mission.

NASA's final maintenance flight comes in 2002, when astronauts will install a new scientific instrument that has yet to be determined. Any equipment that has deteriorated or failed will also be repaired.

It's anybody's guess what will happen after Hubble's nominal mission ends in 2005. NASA may launch a successor, the next-generation space telescope (see above). But what of HST itself? There could be a move to retrieve it to a place of honor in the Smithsonian Institution. But more likely, Hubble will burn up as it re-enters Earth's atmosphere, just like any other space derelict.

For now, though, the picture show continues. Pull up a chair . . . the best is yet to come! ☐

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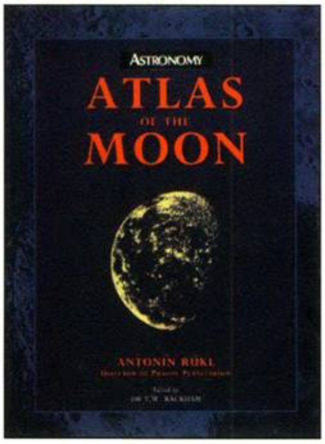

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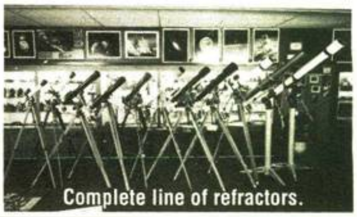

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Young BRIGHT & BLUE

Are colliding galaxies and globular clusters linked? Galactic collisions may set the stage from which these clusters are born.

by Patti A. Kurtz

Jon Holtzman of New Mexico State University and colleagues found something peculiar in NGC 1275 — compact objects that appear to be young globular clusters. This discovery intrigued them because most globular clusters are among the oldest known objects in the universe. These new objects are different — they're young, bright, and blue.

The 1991 discovery caused Holtzman and others to wonder what was special about NGC 1275. Why does this galaxy have young globular clusters?

Two hypotheses attempt to answer the question. The first takes into account that NGC 1275 is at the center of a cluster of galaxies called the Perseus Cluster. A lot of gas flows from within the cluster onto the central galaxy. This process is known as a cooling flow. Some astronomers believe this gas forms into stars and/or star clusters.

Another theory is based on evidence that NGC 1275 may have recently collided with another galaxy. The collision, some astronomers believe, sparked the formation of the young clusters.

Using the Hubble Space Telescope in 1994, Holtzman's group observed two colliding galaxies (NGC 3597 and NGC 6052) and four central galaxies (Abell 1795, Abell 496, Abell 2029, and Abell 2597) in cooling flow clusters. Both colliding galaxies show evidence for massive clusters of stars, whereas most of the cluster galaxies observed show none.

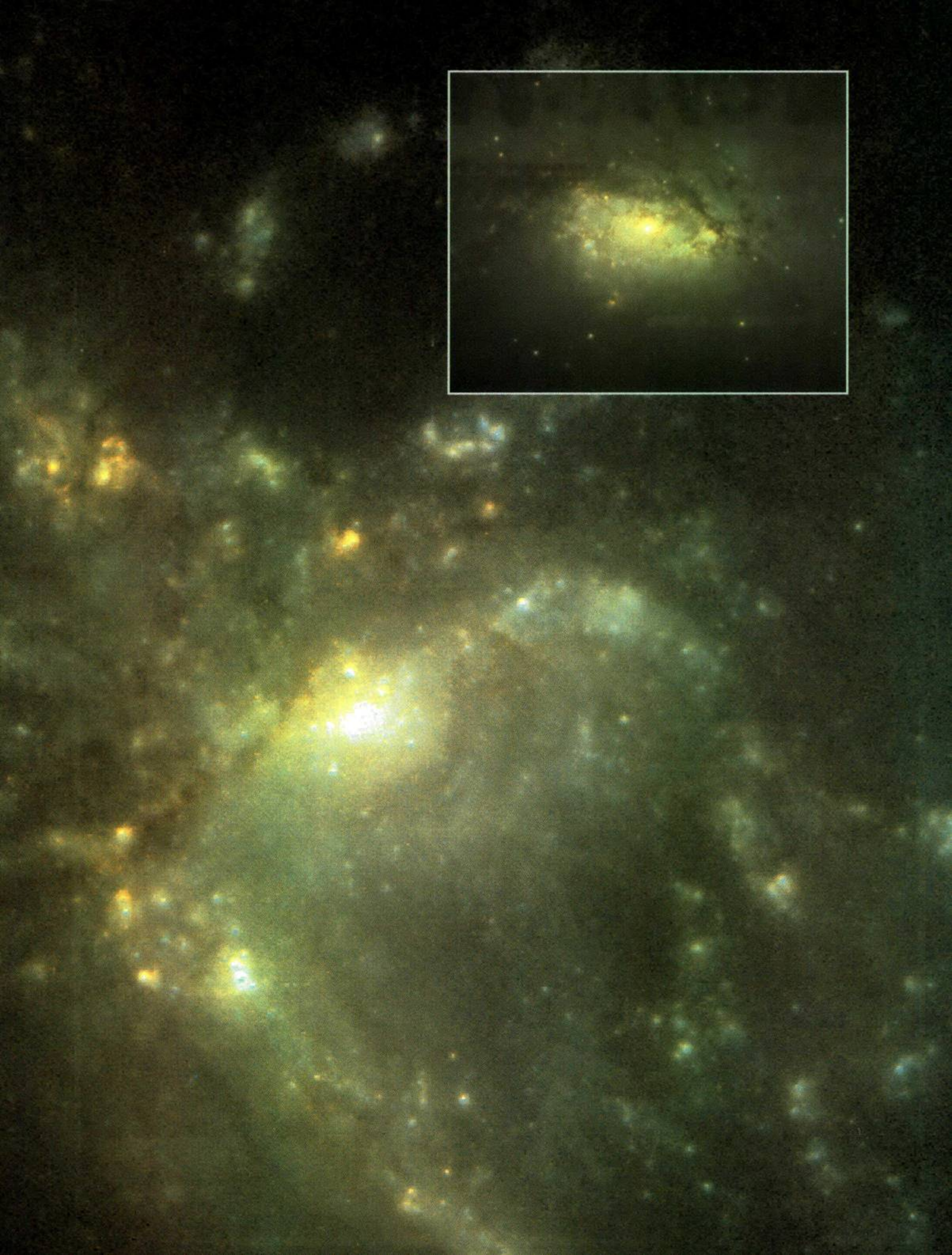
In addition to these observations, astronomers have recently found young globular cluster candidates in several galaxies, most of which are colliding. Evidence is building that globular clusters can be formed when galaxies collide.

What does this mean? Some astronomers believe that colliding spiral galaxies form elliptical galaxies (see "Galaxies Colliding in the Night," November 1996). However, most elliptical galaxies have more globulars than do spirals of comparable brightness. If an elliptical galaxy forms by the merging of two spirals, the ratio of the number of globular clusters to the total brightness of the galaxy shouldn't change. But if globulars form during the merger, the increased number of globular clusters might be explained.

Holtzman has also been analyzing the clusters' sizes to confirm they are compact enough to be comparable to their older counterparts, which usually have diameters of a few parsecs. The resulting measurements suggest that the objects in NGC 3597 are as compact as Milky Way globulars, implying that they may survive as distinct entities for 10 billion years and eventually look like typical globular clusters. ☐

Jon A. Holtzman, Alan M. Watson (New Mexico State Univ.), and Jay S. Gallagher (Univ. of Wisconsin), et. al., and NASA.

These photos led astronomers to their targets — young globular star cluster candidates in the making. The blue objects in and around NGC 6052 and NGC 3597 (inset) may have formed when galaxies collided.



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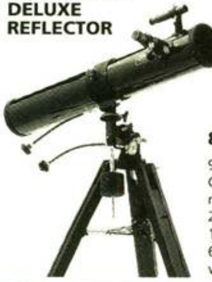

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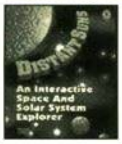

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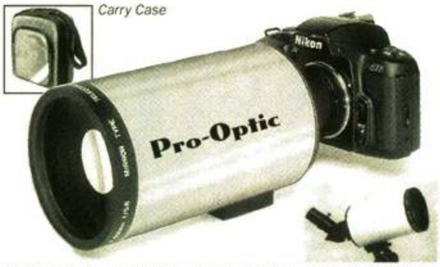

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SKY ALMANAC

Anticipation builds as Mars and Comet Hale-Bopp brighten to share the spotlight with no fewer than four morning planets.

by Martin Ratcliffe

Highlights
by Rick Shaffer

Date	Event
5	A Lowdown View of Three Planets . .(p. 70)
10	Night of the Moon and Saturn . . . .(p. 70)
22	**First Views:** Full Moon and Lunar Rays . . . .(p. 72)
28	Jupiter's Return and the Red Spot . .(p. 72)
all month:	Mars Approaches Opposition . . . . . .(p. 69)
	Observer's Challenge: Galaxies in Orion . . . .(p. 71)
	Happy Birthday Mira . . . .(p. 73)

Will 1997 be remembered as the year of Comet Hale-Bopp or the year of Mars?

During February, Comet Hale-Bopp brightens to near 3rd magnitude, with a lengthening tail in the morning sky. Meanwhile, Mars begins its best display in two years as it approaches a March opposition.

First let's consider **Comet Hale-Bopp**, which is making its first appearance in Earth's sky in many thousands of years. It swings into action this month by moving from Aquila, across Sagitta and Vulpecula, into Cygnus, and brightening by a whole magnitude. February sees the comet stand at its highest elevation above the predawn horizon.

On February 6, Hale-Bopp passes close to the comparatively dim 8th-magnitude globular cluster M71 in Sagitta. Four days later the comet's tail wafts across M27, the Dumbbell Nebula, a well-known planetary in Vulpecula. It will certainly be worth giving up a few hours' sleep to witness this rare spectacle.

Hale-Bopp spends the entire month traveling along the Milky Way's glowing path. This superimposition may make the tail's fainter extremities a little hard to see, as happened with Comet Halley in March 1986 for Southern Hemisphere observers.

Around the time of new Moon on February 7, the comet rises more than three hours before the Sun. By the end of the month it's rising four hours ahead of the Sun. The comet will continue to brighten through March.

Chris Schur

Comet Hale-Bopp will sport two tails as it draws closer to the Sun. In this photo taken last fall, the Sun's ultraviolet radiation makes gas given off by the comet glow blue. This month Hale-Bopp sprouts a yellowish dust tail that reflects sunlight as well.

Meanwhile, **Mars** continues its own upward trend in brightness. Somehow this reddish globe will feel different to observers this year as it glows in the night sky.

Mars has long conjured up thoughts of extraterrestrial life, ever since Percival Lowell planted the idea a century ago that Martians built canals.

In a case where life almost imitates expectations, NASA announced last year that traces of ancient microbial life were found in a rock blasted from Mars millions of years ago.

The meteorite's enigmatic testament has inspired renewed interest in the Red Planet. And as an armada of high-tech spacecraft makes its way to Mars to discover more about our intriguing neighbor, backyard astronomers will make discoveries of their own.

Not long after twilight hands off to the cold darkness of night, Mars beckons on the eastern horizon. It resides among the stars of Virgo the Virgin all month and shines at a brilliant magnitude of –0.6, far outshining Spica to the southeast.

Mars will be at its brightest and closest to Earth in more than two years when it comes to opposition in March. That's when Earth lies directly between Mars and the Sun.

This happens roughly once a year for most planets beyond Earth's orbit. But closer Mars moves faster than those outer planets, so it takes longer for Earth to catch up to its relative position in space. Oppositions for Mars come roughly every two years and 50 days.

1997
FEBRUARY

1 Venus passes 1.0° south of Neptune, 6 a.m. EST

3 Asteroid Vesta is in conjunction with the Sun

5 Venus passes 0.3° south of Jupiter, 7 p.m. EST
The Moon passes 5° north of Mercury, 11 p.m. EST

6 The Moon passes 4° north of Neptune, 3 a.m. EST
Mars is stationary, 1 p.m. EST

7 Venus passes 0.2° south of Uranus, 7 a.m. EST
New Moon is at 10:06 a.m. EST
Mercury passes 1.4° south of Neptune, 3 p.m. EST
The Moon is at perigee (356,847 kilometers from Earth), 3:40 p.m. EST

10 The Moon passes 1.8° north of Saturn, noon EST (page 70)

12 Mercury passes 1.0° south of Jupiter, 9 a.m. EST
Mercury passes 0.9° south of Uranus, 7 p.m. EST

14 First quarter Moon is at 3:57 a.m. EST

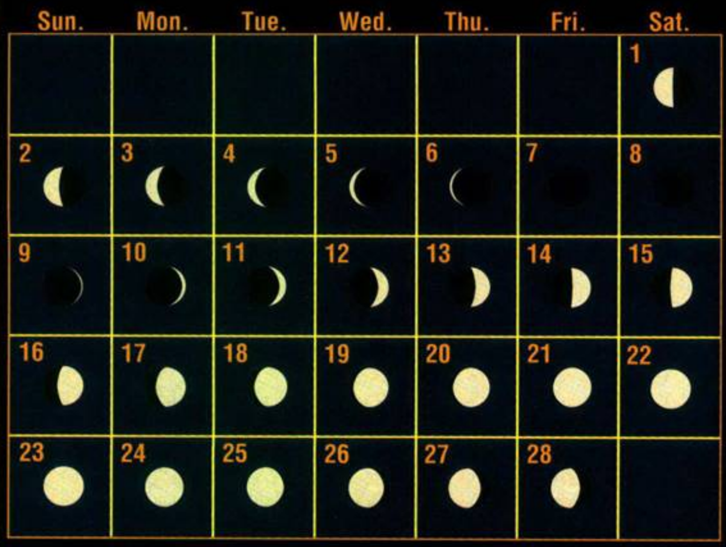
15 The Moon passes 0.6° north of Aldebaran, 6 a.m. EST

16 Jupiter passes 0.2° north of Uranus, 3 a.m. EST

21 The Moon is at apogee (406,395 kilometers from Earth), 12:07 p.m. EST

22 Full Moon is at 5:27 a.m. EST (page 72)

24 The Moon passes 3° south of Mars, 8 p.m. EST


Sun.
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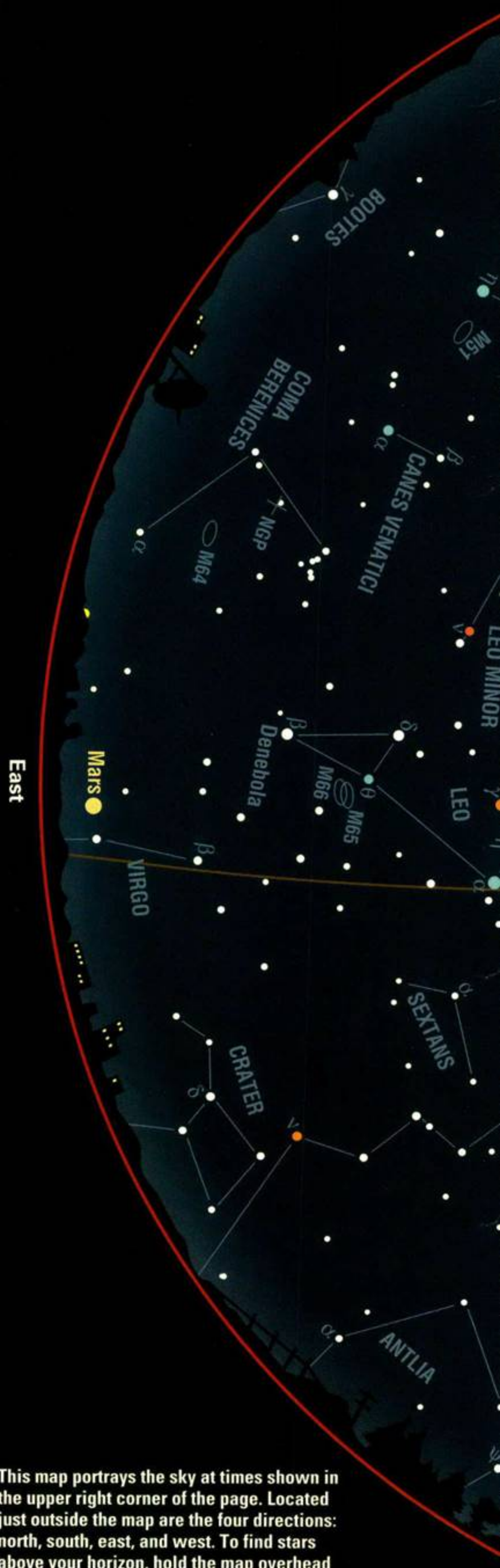
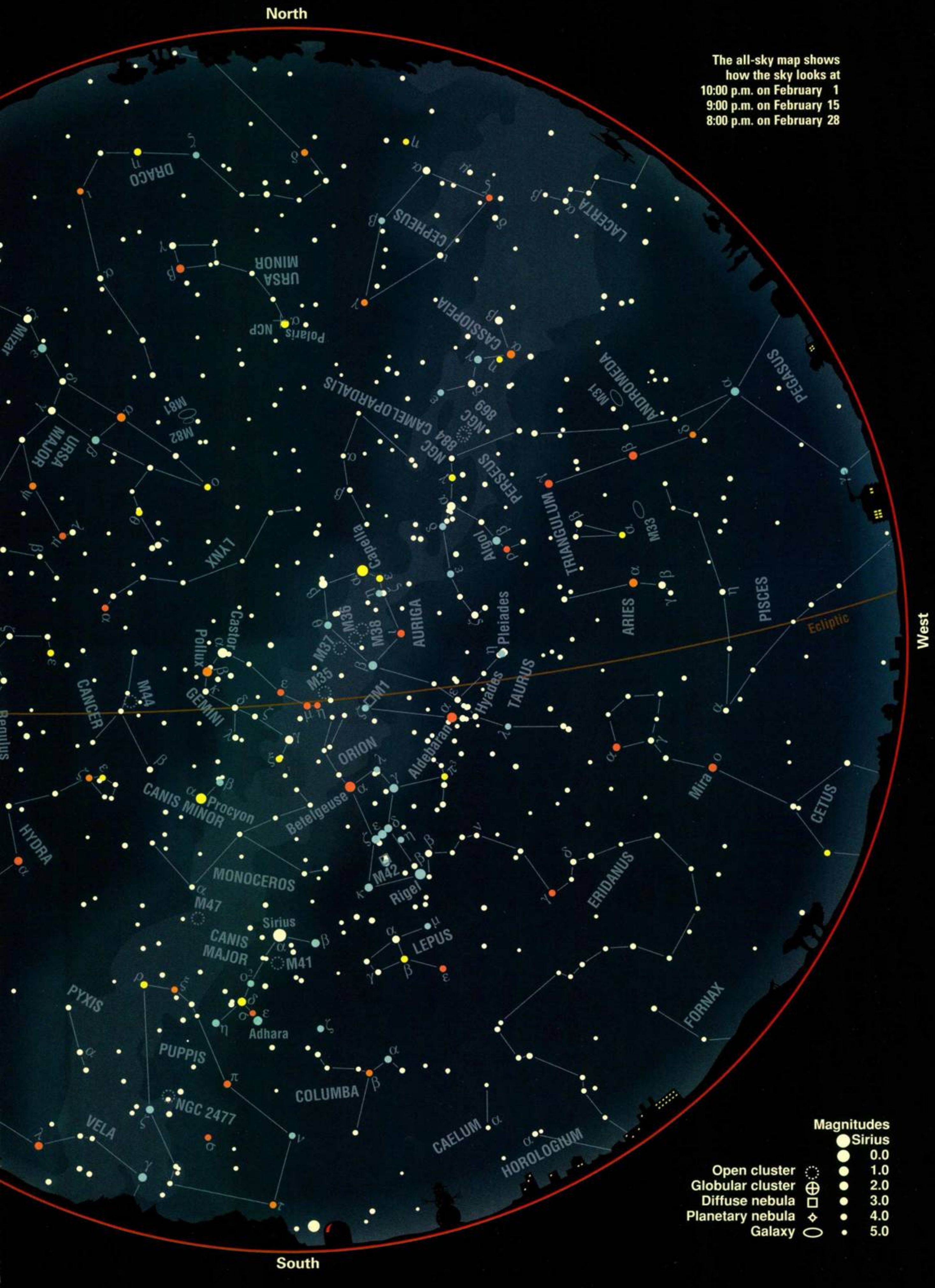

East
BOOTES
M51
COMA BERENICES
CANES VENATICI
NGP
M64
LEO MINOR
Mars
Denebola
M66
M65
LEO
VIRGO
SEXTANS
CRATER
ANTLIA

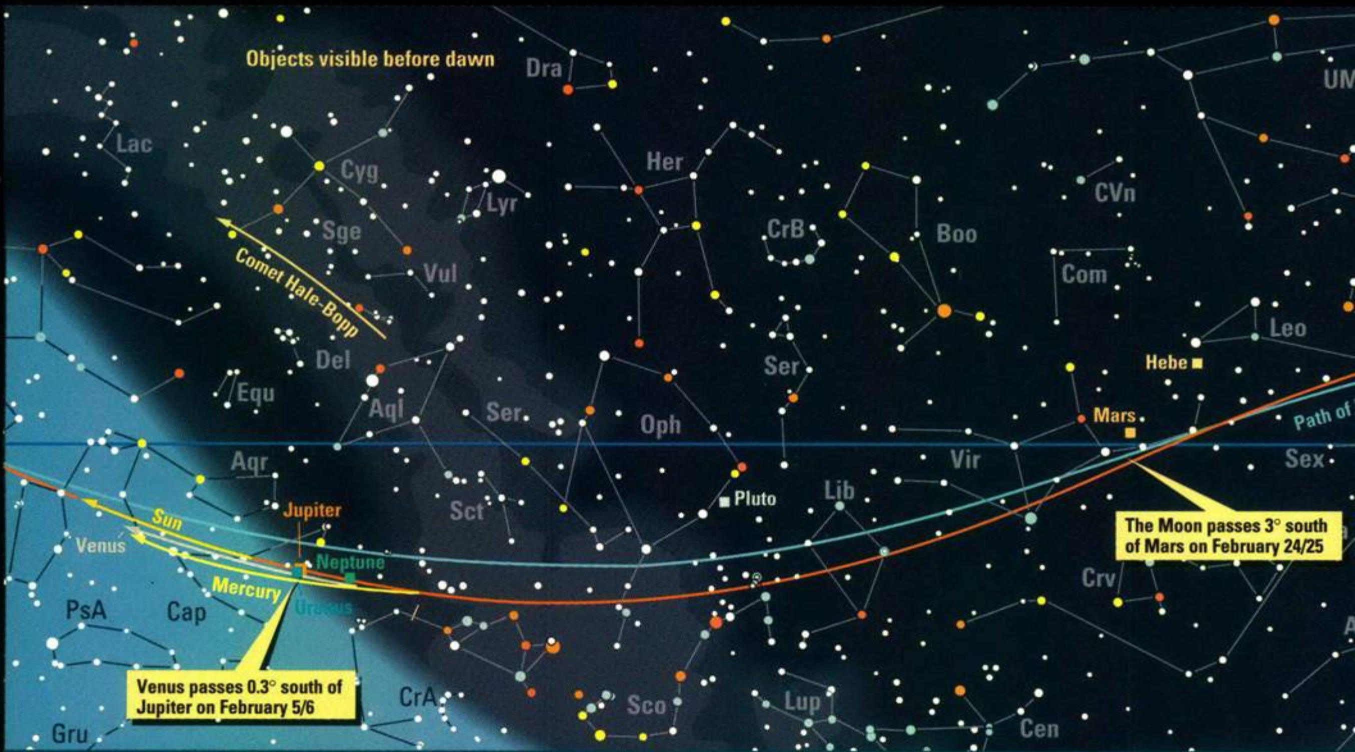
This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



The all-sky map shows how the sky looks at
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28

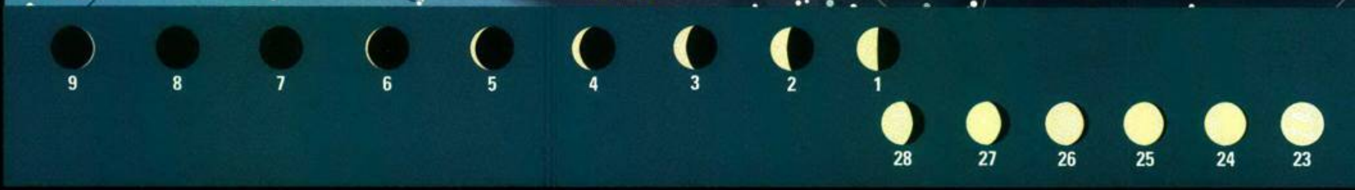
North
South
West
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris
NCP
Mizar
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
CAMELOPARDALIS
NGC 869
NGC 884
M81
M82
URSA MAJOR
PERSEUS
TRIANGULUM
M33
Algol
LYNX
Capella
AURIGA
ARIES
PISCES
Ecliptic
M36
M38
M37
Pleiades
Castor
Pollux
M35
M1
Hyades
TAURUS
CANCER
M44
GEMINI
Regulus
Aldebaran
ORION
Mira
CETUS
CANIS MINOR
Procyon
Betelgeuse
HYDRA
MONOCEROS
M42
Rigel
ERIDANUS
M47
Sirius
CANIS MAJOR
M41
LEPUS
PYXIS
Adhara
FORNAX
PUPPIS
COLUMBA
NGC 2477
VELA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
Dra
UM
Lac
Cyg
Lyr
Her
Sge
Vul
Comet Hale-Bopp
CrB
Boo
CVn
Com
Del
Ser
Leo
Hebe
Equ
Aql
Ser
Oph
Mars
Path of
Aqr
Vir
Sex
Jupiter
Pluto
Lib
Sun
Sct
Venus
Neptune
Mercury
Uranus
Crv
PsA
Cap
A
CrA
Sco
Lup
Cen
Gru

The Moon passes 3° south of Mars on February 24/25

Venus passes 0.3° south of Jupiter on February 5/6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23

10"

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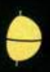
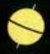
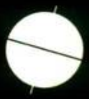
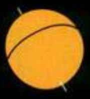
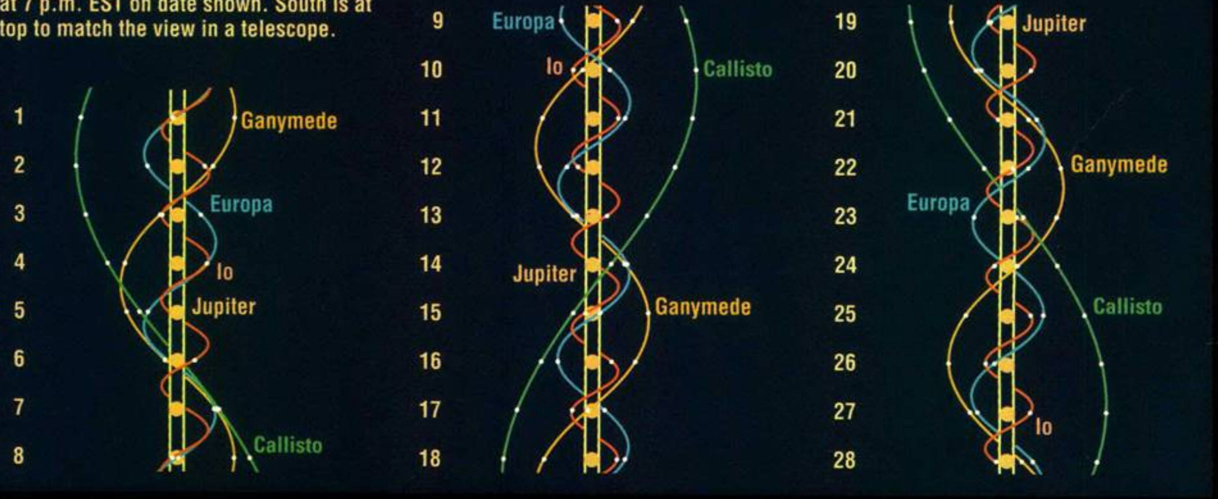
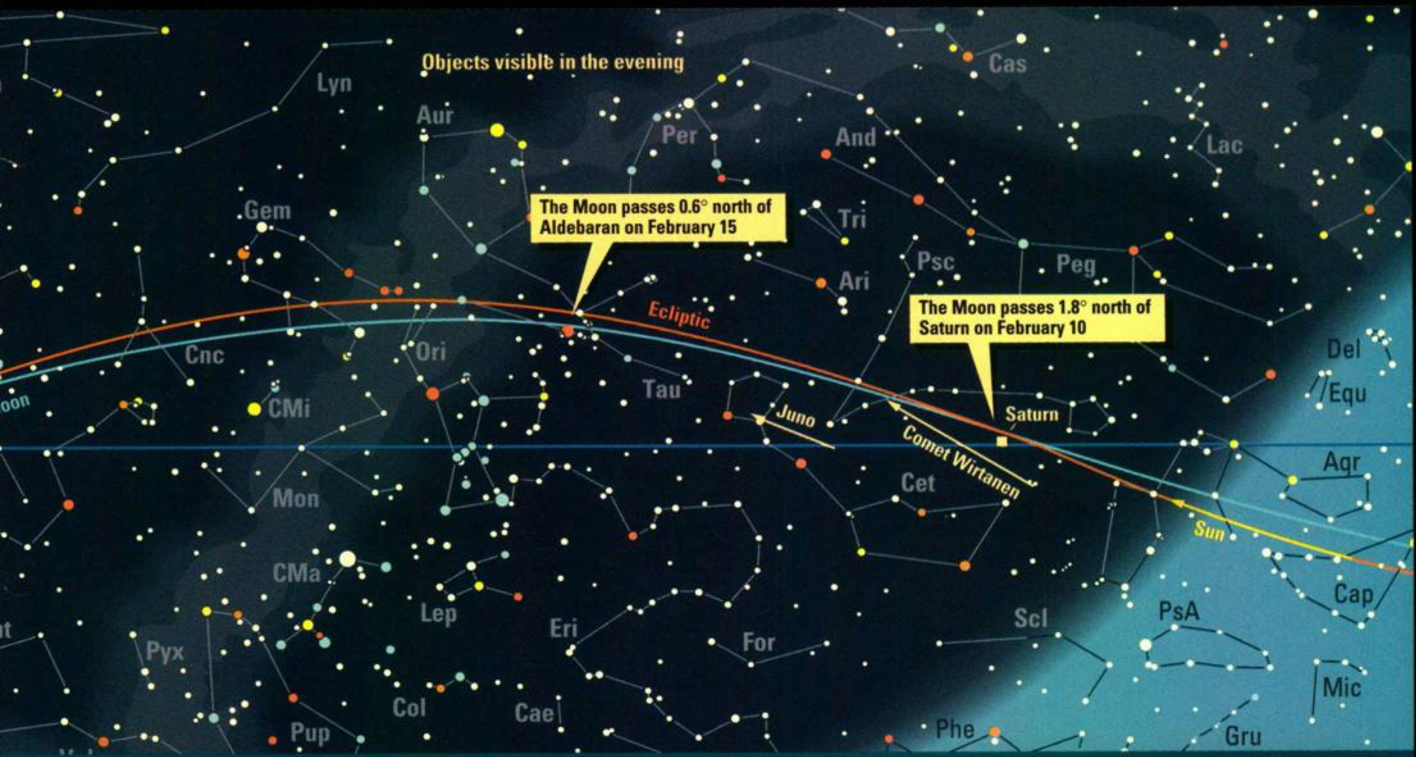
PLANETS	MERCURY	MERCURY	VENUS	MARS	MARS
Date	February 1	February 28	February 15	February 1	February 28
Magnitude	–0.1	–0.8	–3.9	–0.2	–1.0
Angular Size	5.9"	4.9"	10.0"	10.6"	13.3"
Illumination	75%	96%	98%	94%	99%
Distance (AU) from Earth	1.131	1.368	1.668	0.881	0.706
Distance (AU) from Sun	0.452	0.428	0.728	1.666	1.661
Right Ascension (2000.0)	19h21.5m	22h10.5m	21h10.4m	12h26.6m	12h16.6m
Declination (2000.0)	–22°09'	–13°34'	–17°20'	0°45'	2°20'

JUPITER'S MOONS

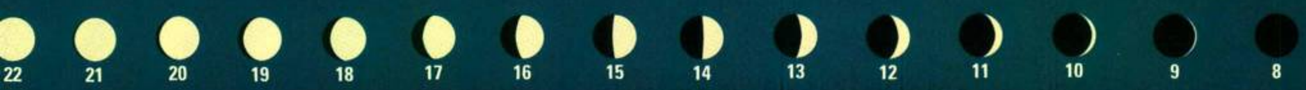
Dots display positions of Galilean satellites at 7 p.m. EST on date shown. South is at top to match the view in a telescope.




Objects visible in the evening
Lyn
Aur
Per
And
Cas
Lac
Gem
Tri
Ari
Psc
Peg
Ecliptic
Cnc
Ori
Tau
Del
Equ
oon
CMi
Juno
Comet Wirtanen
Saturn
Aqr
Mon
Cet
Sun
CMa
Lep
Eri
For
Scl
PsA
Cap
Pyx
Col
Cae
Pup
Phe
Gru
Mic

The Moon passes 0.6° north of Aldebaran on February 15

The Moon passes 1.8° north of Saturn on February 10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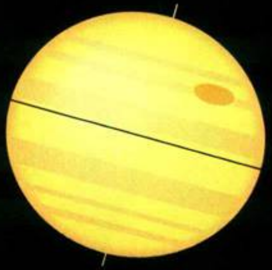
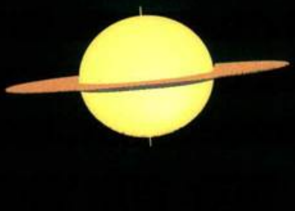
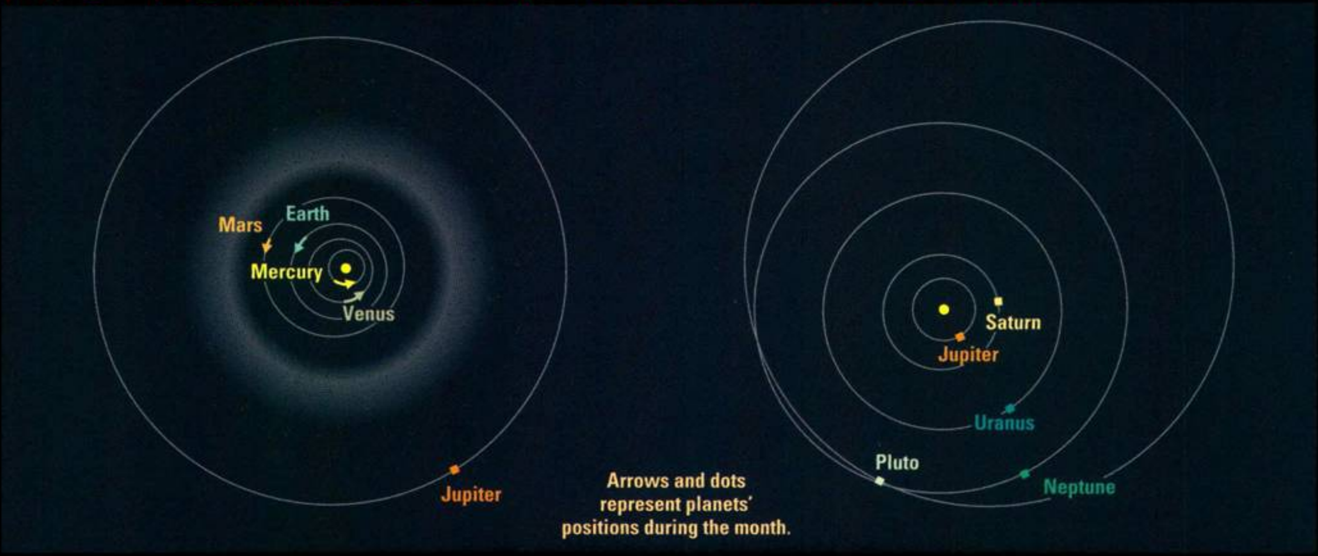




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15
–1.9	1.0	5.9	8.0	13.8
32.7"	16.3"	3.4"	2.2"	0.1"
100%	100%	100%	100%	100%
6.034	10.208	20.726	31.024	30.094
5.121	9.458	19.803	30.155	29.958
20h32.8m	0h22.1m	20h33.7m	20h02.3m	16h23.8m
–19°14'	–0°02'	–19°21'	–20°03'	–8°49'

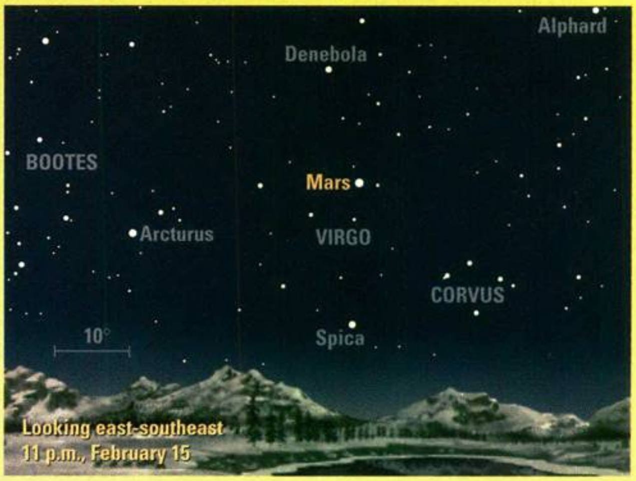
THE PLANETS IN THEIR ORBITS


Mars
Earth
Mercury
Venus
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Arrows and dots represent planets' positions during the month.

Mars Approaches Opposition

Don Parker



Looking east-southeast
11 p.m., February 15

After a seemingly interminable time out of the spotlight, Mars is once again approaching opposition. That happens next month, when the Red Planet's disk is a bit over 14" in apparent diameter. This month, Mars barely reaches 13", and starts off the month under 11" in apparent diameter.

So why not wait until March, when it'll be bigger? The answer is in the subtleties of observing Mars. With the exception of the polar ice caps, most of its surface features require an experienced eye to detect. You'll have to put in a little practice to see those subtle surface details when Mars reaches opposition in March.

One way you can optimize the view is to observe from a site that doesn't look over sources of heat, such as your neighbor's poorly insulated home. Heat rising from the roof will create turbulence that will ruin your view of Mars.

After attending to that, just what can you expect to see on Mars?

The north pole of Mars is tilted toward us and the Sun during February and March, so its white polar cap ought to be the most obvious feature seen in even the smallest telescopes.

Other, more subtle surface details are visible as well. Dark, splotchy albedo markings are features caused by the contrast between rougher and smoother areas on Mars' surface. The smooth areas look reddish, and are sand spread over craters and eroded areas. The darker regions show where wind has scoured the surface free of sand.

Although reddish-gray, these areas often appear dark in contrast to the lighter-red areas. If you see a change in the appearance of an area on Mars, it's because wind has either left some dust there or removed it. A red, thread-in eyepiece filter will enhance the contrast between the light and dark areas.

One final thing to keep in mind. Your view of Mars might seem to change from night after night. That's because the rotation period of Mars is 37 minutes longer than ours. If you observe at the same time every night, the planet's features will slowly creep from east to west.

Happy (subtle) viewing! — *Rick Shaffer*

The approaching opposition offers an opportunity for us to see light and dark features on Mars through a telescope. During February the planet's apparent diameter exceeds 10", an angular size above which most observers begin to spot large surface markings with relative ease.

Use medium power and wait for elusive moments of steady seeing. Now and then the atmosphere you're viewing through becomes calm enough to reveal detail on the planet's disk. These moments are worth waiting for.

Mars' north polar cap should show up as a brilliant white spot on an otherwise yellow-orange disk. Views of one or two dark markings, such as wedge-shaped Syrtis Major, can be enhanced by threading a Wratten #25 red filter (check the ads in this magazine) into an eyepiece.

By February 28, Mars' apparent size swells to 13" as Earth draws to within 106 million kilometers.

You won't need a telescope to watch Mars shift against the starry background from night to night. The planet's movement demonstrates the most dramatic example of what's called retrograde motion.

As Earth overtakes Mars in the weeks approaching opposition, the Red Planet appears to move backward, or retrograde, against the fixed stars and constellations.

Something similar happens when you pass a car on the highway — the slower vehicle, still moving forward, appears to move backwards as you overtake it.

Track this motion by plotting Mars' nightly position on a star map, or with a series of 30-second exposures through a camera set on a sturdy tripod using fast film.

By the end of the first week of February, the planet's normal easterly path slows and begins to double back upon itself at a point 2° northeast of Eta (η) Virginis. This westerly, retrograde path continues until late April.

Saturn joins Mars in the evening sky as a bright 1st-magnitude "star" in the west-southwest after sunset. It's the brightest object in an otherwise lackluster part of the sky.

Once darkness falls, look for Saturn in line with the left-hand side of the Great Square of Pegasus, marked by the stars Alpha (α) Andromedae and Gamma (γ) Pegasi.

When viewed through a telescope, Saturn's rings are one of the most appealing views in the heavens. This month they tilt 5° to our line of sight, opening up even wider in the coming months.

A telescope as small as 70mm might pick up a dark gap in the rings called the Cassini Division.

An astrophoto

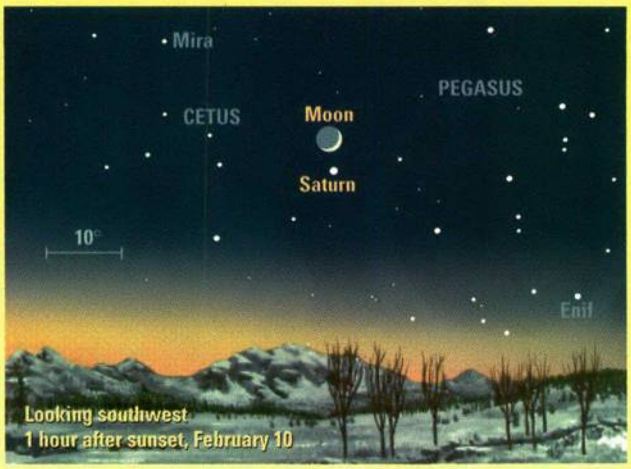
opportunity arrives on the evening of February 10 when a four-day-old waxing crescent Moon lies less than 5° to the northeast of Saturn. Earlier in the day, near noon for North Americans, the Moon passed less than 2° north of the Ringed Planet.

As Saturn sets in the west by midevening, the majestic Andromeda Galaxy, also known as M31, lingers in the northwest. Its fuzzy appearance in binoculars hides the fact that it is home to more stars than our own Milky Way.

If your skies are dark enough, look for M31 without binoculars. Its feeble light takes 2.2 million years to reach your eyes. Comet Hale-Bopp will pass near this giant spiral galaxy in March.

There's a far more elusive glow than M31 visi-

Night of the Moon and Saturn



Looking southwest
1 hour after sunset, February 10

On the evening of February 10, the Moon lies less than 5° north of Saturn. The Moon passing near Saturn is always worth a look, if only to compare the lovely butterscotch hues of Saturn with the gray-green of the Moon.

It's also an obvious photo opportunity. Record the pairing with such photogenic scenes as your local church or some big, well-lit downtown skyscrapers.

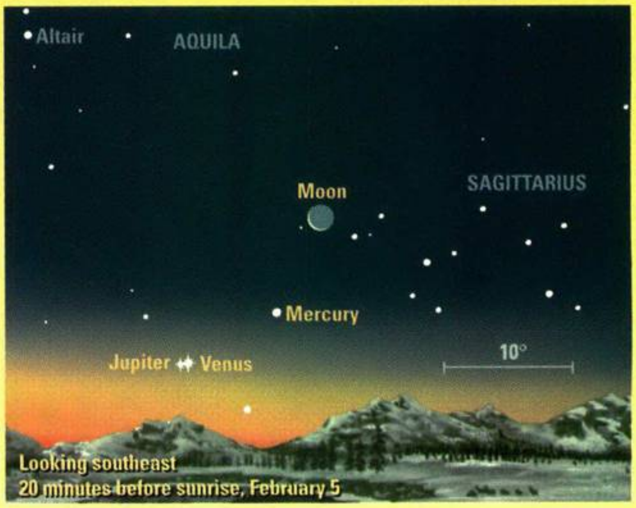
Load a single-lens-reflex camera with 400-speed film, then take time exposures of 8, 16, 30, and 60 seconds with the camera mounted on a tripod. To ensure a really sharp image, click the lens aperture down one or two settings from wide open. Set the focus to infinity.

You can also use this conjunction to demonstrate the motion of our Moon around Earth. Note the relative positions of Saturn and the Moon the night before conjunction.

Either photograph the scene or draw a sketch. Now keep track of how the Moon's movement progresses the following two evenings.

This motion from night to night is our natural satellite moving in its orbit around the Earth at 3,700 kilometers (2,300 miles) an hour. — *R. S.*

A Lowdown View of Three Planets



Looking southeast
20 minutes before sunrise, February 5

You may wonder where all the planets have gone this month. Four lurk close to Sun. Three lie so low in the morning sky that it takes considerable observing skill to find them.

Let's start our search on the morning of February 5.

Mercury is easy to find, especially since it will be just 8° below the 27-day-old Moon. Look for it about 45 minutes before sunrise; its phase will appear gibbous through a telescope.

As the dawn sky brightens, Venus and Jupiter pop over the eastern horizon about 30 minutes before sunrise. The brighter of the two is Venus, at magnitude –3.9. It's just finishing a long morning apparition before moving into the evening sky.

Jupiter glows two magnitudes dimmer than Venus and lies only 37" away, just over the width of a full Moon. Unlike Venus, Jupiter is leaving its alignment with the Sun.

Over the next 13 months, it will climb higher into the morning sky and pass into the evening sky before heading behind the Sun once again.

Jupiter is farther from the Sun than Earth, so astronomers call it a superior planet. Mars, Saturn, Uranus, Neptune, and Pluto also fall into this group. Like the other superior planets, Jupiter's orbital motion is slower than ours, so its apparent motion in our sky is dominated by the faster orbital motion of our viewing platform, Earth.

Venus and Mercury are closer to the Sun than Earth, so they are termed the inferior planets. They have faster orbital motions than Earth, so their apparent motion in our sky is dominated by their motion relative to the Sun, not our orbital motion.

This means they go through an endless cycle of apparitions in the evening sky, followed by dips into the morning sky, and so on. — *R. S.*

ble during the moonless evenings of February and March. It's called the zodiacal light, and its origin lies within our own solar system.

The zodiacal light is difficult to identify first time around, but here's what to look for. Start with a very clear, moonless night away from city lights. Once twilight has faded and if conditions are right, you may detect a faint pearly-white, cone-shaped glow in the west that reaches up from the horizon through Aries into Taurus.

This faint glow lies in the orbital plane of our solar system. This plane, also called the ecliptic, stands at a steep angle to the western horizon after sunset during spring.

Consequently February, March, and April are the best times of year in the evening to spot sunlight that scatters off billions of tiny grains of interplanetary dust to create zodiacal light.

After glimpsing the zodiacal light, Mars, and Saturn, it's a long wait until any obvious solar system object comes into view. The other planets congregate in the bright morning sky to offer a number of conjunctions during February.

These gatherings will challenge any observer, as many of them happen in bright twilight. To increase your chances of seeing them, select a site that overlooks a clear, unobstructed eastern horizon.

On February 1, magnitude –3.9 **Venus** lies 1° south of 8th-magnitude **Neptune**. The two planets rise in the east-southeast a little over half an hour before the Sun, which means Venus should be a cinch to spot. Neptune, however, will be a challenge in the brightening predawn sky.

By February 5, Venus gets a visit from magnitude –1.9 Jupiter, which passes within 0.3°. The morning before and after this closest approach, they lie a mere 0.7° apart. A beautiful crescent Moon joins the grouping 4° to the northwest on February 6.

Venus will become increasingly difficult to follow in the coming days as it sinks deeper into morning twilight.

By February 7 it lies just 13° from the Sun. However, observers at more southerly latitudes might catch **Uranus** a mere 0.2° north of Venus that morning. **Mercury** lies a little less than 2° south of Neptune on the same morning, rising an hour before the Sun.

On February 7, Mercury joins Venus and Jupiter within a circle just 8° across. This grouping

Observer's Challenge:
Galaxies In Orion

When we look at the constellation Orion, we're looking at the next arm of our Galaxy out from the one in which our Sun is located. This means that there's a lot of gas and dust between us and any galaxies that might lie beyond. If we see them at all, they're likely to be really dim.

This reality is reflected in the fact that Orion's better known for glowing gas clouds than galaxies.

Actually, even though they're not very bright, there are some neat galaxies in Orion, most out near his shield. We start with NGC 1713, a 12.7-magnitude elliptical galaxy found 2.5° due south of the 5th-magnitude star Pi^6 (π^6) Orionis.

If you have sufficient aperture, look for NGC 1709 just a bit north of NGC 1713, glowing at magnitude 14.2.

Returning to Pi^6 Orionis, proceed 1.4° east and a little south to pick up NGC 1762, a 12.6-magnitude spiral. Can those of you with 25- to 30-inch telescopes see anything more in the way of structure when you observe it?

Our final galaxy in Orion is, incredibly, 2° west of M42, the great Orion Nebula. It's NGC 1924, a barred-spiral galaxy of magnitude 12.5, making it the brightest of Orion's galaxies. Can observers with anything larger than a 15-inch telescope detect the galaxy's barred-spiral shape?

If this jaunt whets your appetite for winter-galaxy hunting, don't forget that Eridanus the River sprawls west of the Hunter. Its line of sight out of the plane of our Galaxy means it meanders right through a nice field of galaxies. — *R. S.*

StScI/POSS

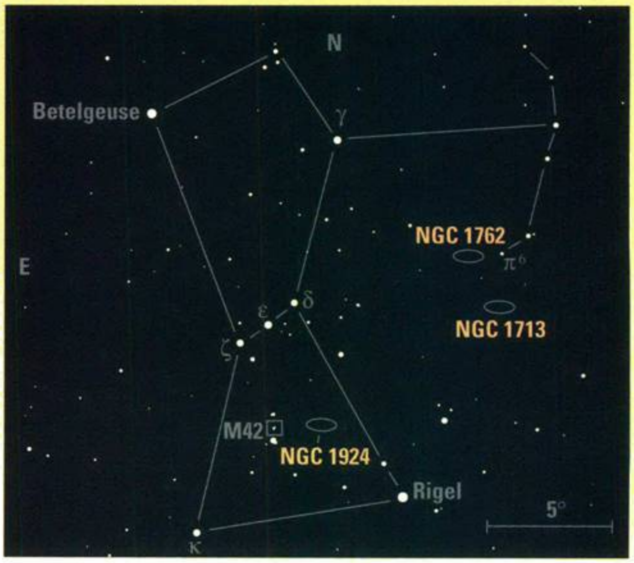
NGC 1924

StScI/POSS

NGC 1713

StScI/POSS

NGC 1762



First Views:
Full Moon and Lunar Rays

Conventional wisdom says if you want to look at mountains, craters, and other relief features on the Moon, you shouldn't observe at or near its full phase. This is because the Sun's rays are beating straight down and cast no shadows for surface relief.

However, there are features on the Moon that benefit from having a Sun high in the sky. They don't rely upon being "bumpy," like a crater, mountain, or fissure.

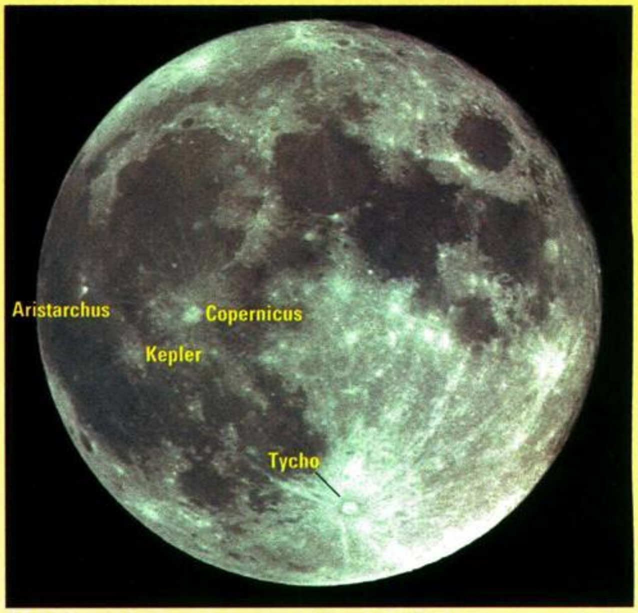
They are, quite literally, splash marks caused when the last of the large asteroids that formed young craters impacted the Moon.

Some of these features, commonly called rays, extend more than halfway across the disk of the Moon. Some of the longest rays spread out from the crater Tycho, found in the southern half of the full Moon.

There are also rays extending away from the great craters of Copernicus, Kepler, and Aristarchus.

These features are easily seen with binoculars or a small telescope. You don't need a huge Dobsonian to see them. Rays look white because they are fresh, unweathered material ejected from relatively young craters, usually a few hundred million years old.

I've found that starting off a beginner on the Moon by talking about the huge "splash marks" is a surefire way of generating some enthusiasm for a discussion of the Moon's violent beginning. — *R. S.*



Alan Dyer

Jupiter's Return and the Red Spot

After passing behind the Sun in January, Jupiter takes all of February to crawl out of the Sun's morning glare. By month's end, it rises 1½ hours before the Sun. If you're an early riser, take the time to unearth your scope for that first view of Jupiter in 1997.

Besides the obvious attraction of Jupiter's belts and zones, the Great Red Spot appears to be making a comeback. For a number of years, its faded appearance often blended with the South Equatorial Belt to appear as only a "bump" in the belt.

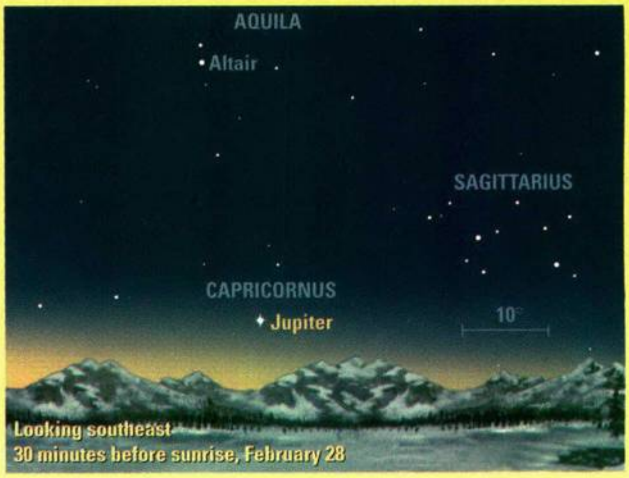
Some astronomers called this the Great Red Spot Hollow. In the latter part of 1996, however, the spot showed signs of getting redder.

As you gaze at the GRS, remember that it's a storm in the cloudtops of Jupiter approximately the size of Earth. The spot wedges itself between the SEB and the South Tropical Zone. It is related to turbulence generated along the border between the belt and the zone, as their velocities differ by approximately 500 kph.

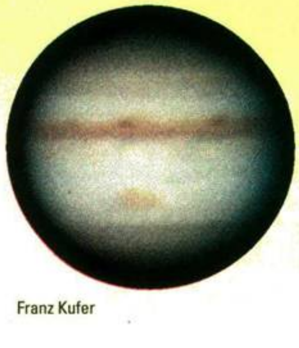
For scientists, Jupiter is one big laboratory for weather, and the Great Red Spot is a study in how atmospheric dynamics create and maintain storms.

The backyard observer can help in these studies. Note the exact time the spot approaches the exact middle of Jupiter's disk. Jot the information on a postcard, along with your name and address, and send it to the American Association of Lunar and Planetary Observers, Jupiter Recorder, 1469 Valleyview Court, Wichita, KS 67212.

ALPO might use your observation to model the Great Red Spot's motion around the cloudtops of Jupiter. The model is useful in predicting the times of future meridian crossings, which will tell you and others when to look to enjoy this wonderful phenomenon. — *R. S.*

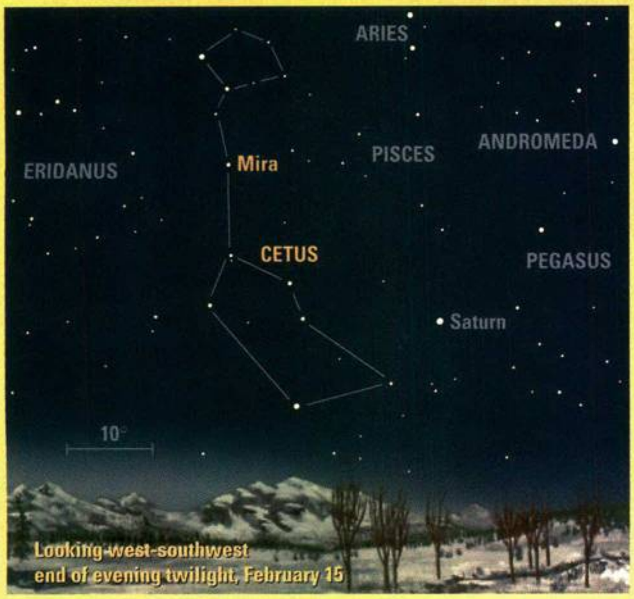


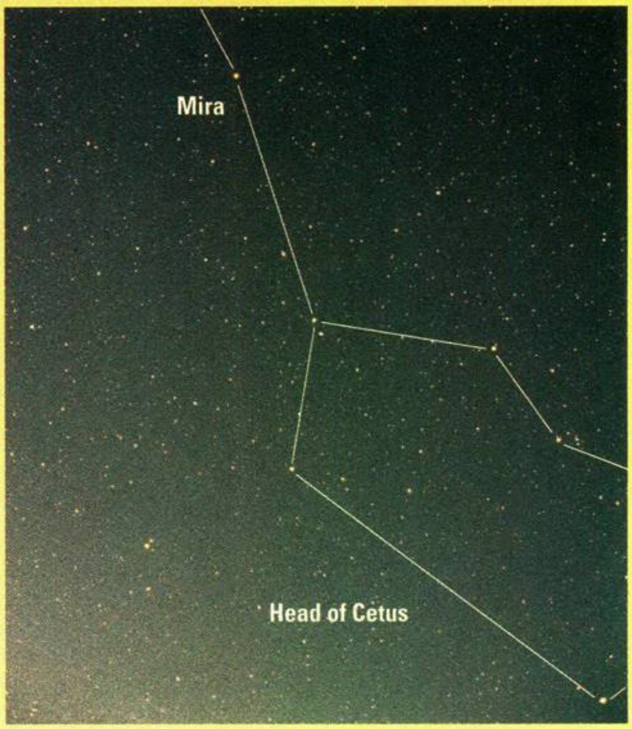
Looking southeast
30 minutes before sunrise, February 28



Franz Kufer

Happy Birthday Mira





Ronald Royer

In August 1596, the astronomer David Fabricius noticed a 3rd-magnitude star in the constellation Cetus the Whale where he had not observed one before. He thought it was a nova and failed to continue his observations.

Eight years later, Johann Bayer included the same star in his atlas as Omicron (o) Ceti, a 4th-magnitude star. Shortly after the atlas' publication, astronomers noticed that Omicron had unaccountably disappeared. Less than a year later, it reappeared at its "normal" brightness.

Astronomers soon realized that Omicron had no normal brightness. It was the first star discovered to regularly vary in brightness, a variable star. For that reason, it was named Mira, "wonderful" in Arabic. Mira's been fluctuating in brightness over a range of about magnitude 3.5 to 9.3 ever since. Its average period is 331 days, which in itself varies from 304 to 353 days.

Mira shines over a huge range of brightness because it pulsates. At 1900 kelvins at minimum brightness, it is one of the coolest stars known. At that temperature, it radiates more energy in the infrared portion of the spectrum, where human eyes are very insensitive.

As it pulses to maximum brightness, Mira warms to about 2500 kelvins, which shifts the peak of its brightness curve more into the red portion of the visible spectrum. Because we can see red light, Mira looks radically brighter.

Last August, when we should have been celebrating the 400th anniversary of Mira's discovery, the star was near its minimum in brightness. It reaches maximum this month, so the celebration has been delayed.

Mira is now an evening object until the end of March, when it slips below naked-eye visibility. Because it only dims to magnitude 9.3 or so, you can use binoculars to follow its changing brightness. — *R. S.*

occurs during twilight, so you might need binoculars to glimpse the trio.

Mercury is finishing up a morning apparition that began last month, and is on its way to passing behind the Sun early next month. Look for the elusive planet 8° southwest of a waning crescent Moon on February 6.

Nearby Jupiter gradually gains on morning twilight as February unfolds. On February 16, look for Uranus just 0.2° south of Jupiter, when both rise just one hour before the Sun. By the end of the month Jupiter is above the horizon an hour and a half before sunrise, with Uranus lying 2° to the west.

Well clear of the Sun's twilight glow, **Pluto** is nonetheless difficult to see due to its feeble, 14th-magnitude glow.

This month it moves from Scorpius into Ophiuchus. By the end of February it lies less than 4° northwest of 2nd-magnitude Zeta (ζ) Ophiuchi.

You'll need a detailed star map and at least an 8-inch telescope to spot this planetary oddball, since it looks for all the world like a dim star. Plotting Pluto's star field each night will betray its telltale track against the stars.

But you'll be forgiven for being distracted from the morning planets this month. February's premier morning visitor, Comet Hale-Bopp, might dominate the scene, perhaps well into the morning twilight.

Upcoming mornings will offer a truly rare opportunity to see a bright comet. Bear in mind the best is yet to come in March and April. □

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is a science writer living in Cornville, Arizona.

Hale–Bopp Takes Center Stage

It's showtime for the widely touted Comet Hale-Bopp. And the audience awaits.

by Patti A. Kurtz

The waiting is over. After a six-week intermission, it's now "curtains-up" for Comet Hale-Bopp (C/1995 O1). Will this much talked-about comet be a flash in the pan, or will it live up to astronomers' hopes and expectations and deliver an award-winning performance?

Although members of the scientific community hold a wide range of opinion, many people think this comet could earn the title "Comet of the Century."

What is it that has had astronomers waiting with great expectation for the last 18 months?

For one thing, Comet Hale-Bopp is big. In fact, Hale-Bopp is huge. Scientists estimate its diameter at 40 kilometers as of press time, compared to most comets that fall in the range of 1 to 10 km across. It was beyond the orbit of Jupiter when it was discovered in July 1995 by Alan Hale and Thomas Bopp. At that time, Hale-Bopp was about 250 times brighter than Comet Halley was at the same distance.

Although it will not come as close to Earth as Comet Hyakutake did on March 25, 1996, Brian Marsden of the International Astronomical Union's Central Bureau for Astronomical Telegrams at the Harvard-Smithsonian Center for Astrophysics, thinks that Hale-Bopp's sheer size could contribute to producing a magnitude of –1.5 to –2.0.

But brightness isn't everything when it comes to rave reviews. In fact, in some minds, tail length is just as important, and not all comets have tails. Comet Hyakutake whizzed past Earth at a distance of 1/10 astronomical unit (AU) or roughly 15 million km (an AU is the average distance from Earth to the Sun — 150 million km). This breathtakingly close approach gave Hyakutake a tail that stretched across 80° of sky. Visible dust tails tend to be more prominent for comets traveling inside Earth's orbit, and at its closest approach on March 22, 1997, Hale-Bopp will be 1.315 AU (about 197 million km) away, roughly ten times farther away than Hyakutake.

The comet's distance from the Sun also affects tail length. Unfortunately, Hale-Bopp will come only 0.91 AU to the Sun — much farther away than most spectacular comets of the 20th century.

However, like many unexpected guests, comets are not exactly predictable, and Comet Hale-Bopp is no exception. According to Charles Morris of the Jet Propulsion Laboratory, in 1995 Hale-Bopp was brightening at a rate that would have made it as bright as Venus (magnitude –4.4). Unfortunately, Morris' analysis of 28 post-conjunction observations from February 24 through September 8, 1996, revealed that the comet's brightening had slowed dramatically. Following his calculations, Morris thinks Comet Hale-Bopp won't reach even 0 magnitude and estimates that it will brighten only to magnitude 1.0. Marsden and his colleague Daniel Green disagree. They feel the original estimates are more accurate. Most observers will be quite pleased with a 1st-magnitude comet, and all, including Morris, are hoping for much brighter.

Unpredictable and Active

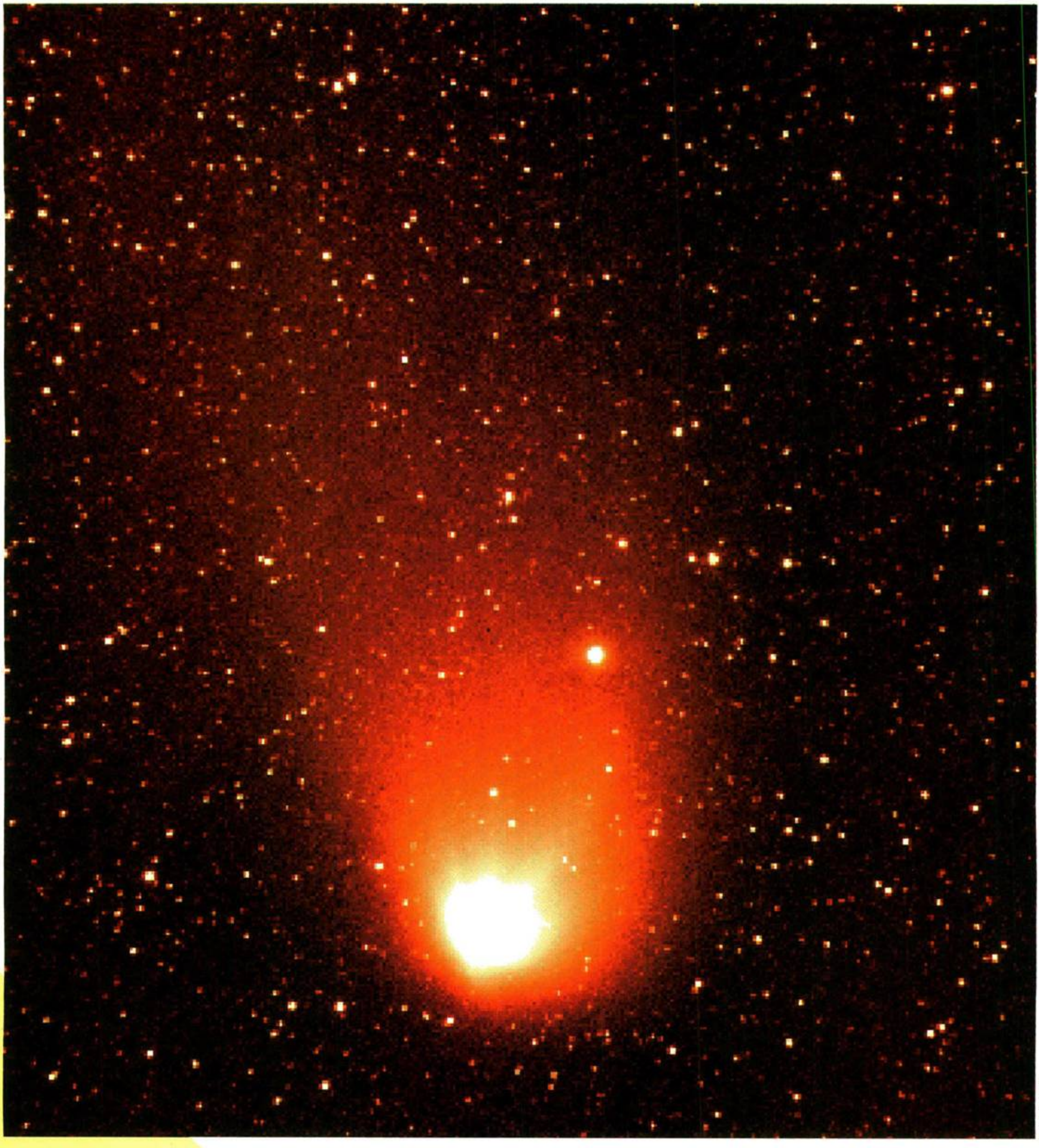
Not only is Hale-Bopp unpredictable, it's extremely active. Since May 1996, amateur observers have noted strong jetting activity both visually and in CCD observations. On August 14-15, Stephen O'Meara and John Bortle saw a bright, "J"-shaped, ever-widening fan spanning some 40-50°, centered close to due north and extending up to 10'.

Additionally, Kurt Birkle of the Centro Astronomico Hispano-Aleman in Almeria, Spain, reported that CCD exposures with a 1.2-meter telescope, "using various filters show the northward fan as three separate structures." An astronomical society in Novara, Italy, used a 0.33-meter reflector to obtain images that showed jets to be faint on May 28 but almost as bright as the main tail by July 31. On August 16, the comet brightened further and developed several secondary jets. Observers remarked that Comet Hale-Bopp resembled a porcupine.

So, get your gear and get in line. This stellar performer hasn't shown up near Earth for about 4,200 years. And don't bother to wait for the next show — it won't be back for another 2,400 years.

Preparing for the Show

Comet Hale-Bopp is an easy naked-eye target by the beginning of February. It is winter, though, and dressing appropriately will make your observing



David Hanon

much more pleasurable (see "Suit up for Winter Observing," January 1997). The warmer you are, the longer you can observe.

Not only is comfort important, light pollution is a factor in enjoying this comet. Get away from the city lights in order to take full advantage of Hale-Bopp's beauty. It will be well worth the measures you take to get yourself and your family and friends to a dark site.

Hale-Bopp blazed through Ophiuchus on September 23, 1996, toward its rendezvous with the Sun — its first such journey in about 4,200 years. This is a false-color image made by David Hanon who imaged the comet for 5 minutes at f/5.5 with an ST-8 CCD camera mounted on a 7-inch refractor.

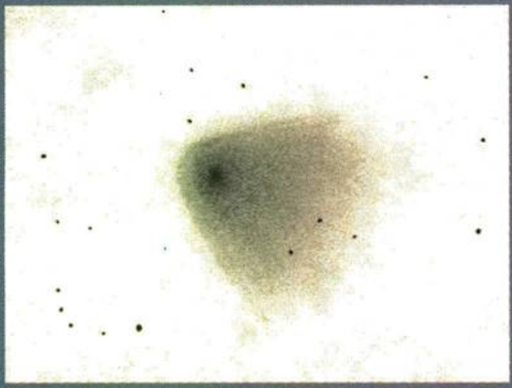
HALE-BOPP'S HISTORY

July 25, 1995

Erich Meyer and Herbert Raab

June 16, 1996

Naruyoshi Ando



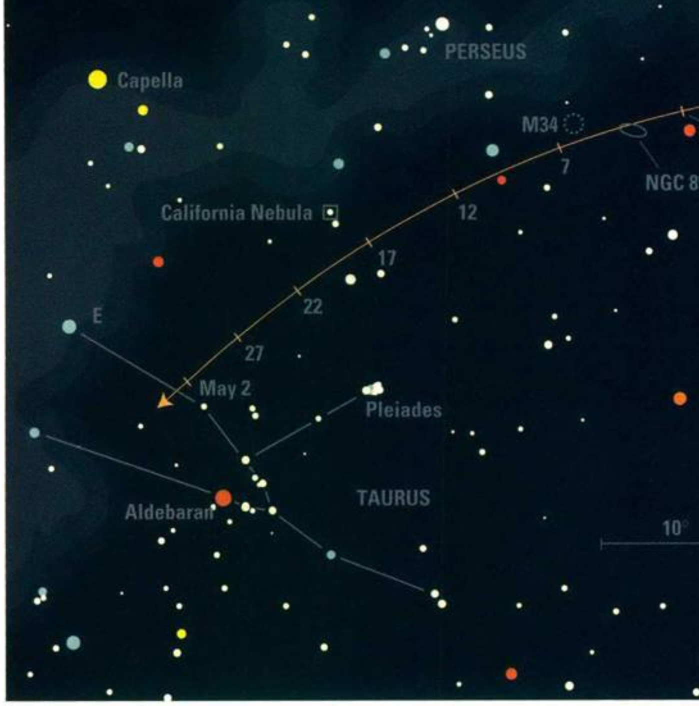
July 22, 1996

Todd Hargis

September 9, 1996

Vince and Maggie Farnsworth

Path of Comet Hale-Bopp



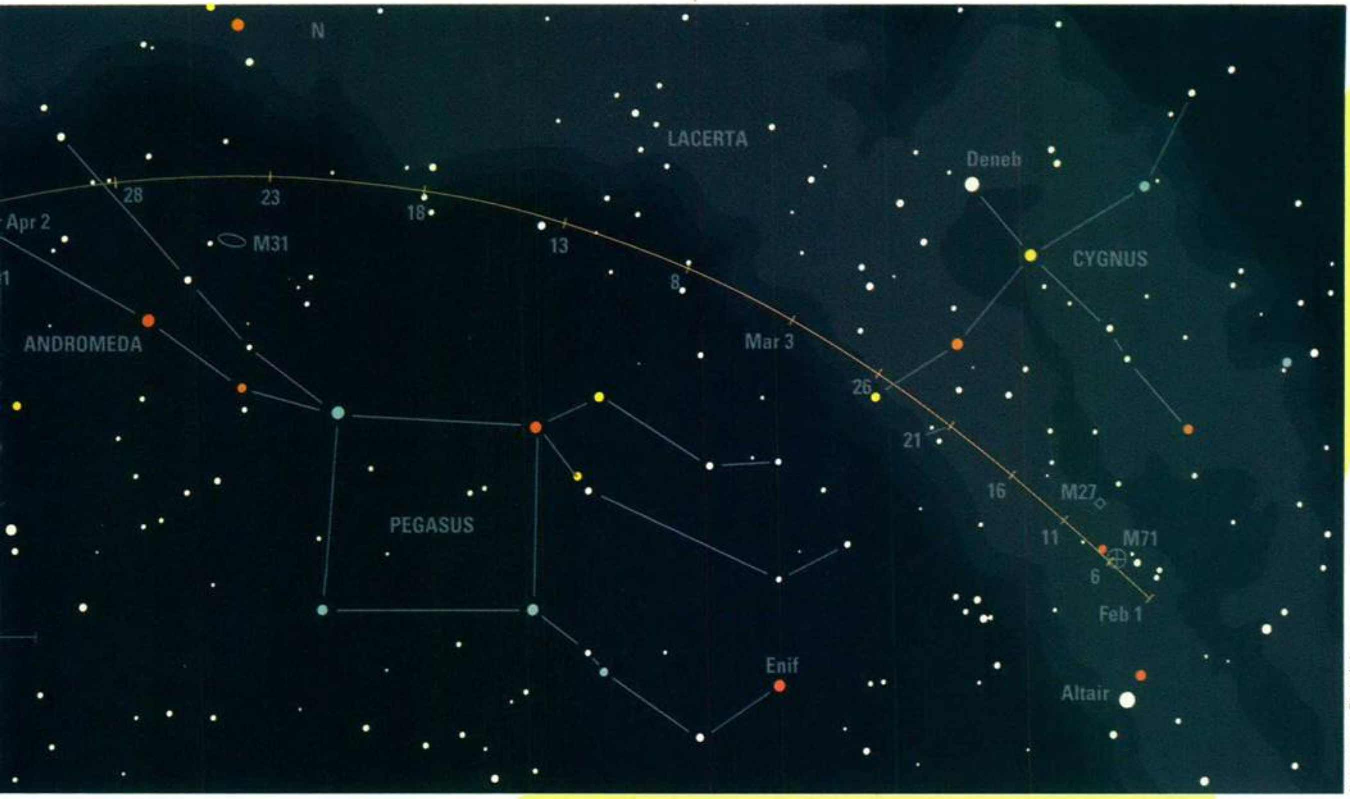
If Comet Hale-Bopp has developed a nice tail, you might be perfectly happy gazing at it without any optical aid because you can see it in its glorious entirety. If you prefer seeing the comet up-close and personal, try out a pair of binoculars and scan the comet and its tail at length. When you've had your fill, move on to a telescope with low magnification. Check out the coma, its hazy atmosphere of gas and dust, and try to imagine its size. In August 1996, Hale-Bopp's coma grew to over one million km across, or roughly the size of the Sun. It could get even bigger as it gets close to the Sun.

What's It Really Like in There?

The nucleus is the source of all the action. It's the dirty snowball hurtling through space that sheds and jets ice, gas, and dust. Although astronomers estimate the comet's size at 40 km, a spokesperson for the Harvard-Smithsonian Center for Astrophysics, says they cannot accurately measure the size of the nucleus while the coma is still active, except in the case of a close rendezvous by spacecraft (as Giotto did with Comet Halley).

With a telescope, see if you notice some activity in the coma. Does Hale-Bopp still look like a prickly porcupine? Keep a journal recording your observations and make sketches of what you see. Even if you never show it to anyone, in 2,400 years, you can check your entries to see how the comet has changed over the millennia. Or, you can use it to compare with the records of other observations that will undoubtedly show up in the pages of ASTRONOMY. It will also be interesting to compare it to other comets in the coming years.

In addition to sketching and keeping a journal, you might record Hale-Bopp by photographing it. Next



ASTRONOMY: Rick Johnson

Where to Find Comet Hale-Bopp

Date	R.A (2000)	Dec.	Mag.	Date	R.A (2000)	Dec.	Mag.
Feb. 1	19h43.4m	+16°03	0.8	Feb. 16	20h28.6m	+24°43	–0.1
Feb. 4	19h51.1m	+17°34	0.6	Feb. 19	20h40.2m	+26°47	–0.3
Feb. 7	19h59.4m	+19°12	0.4	Feb. 22	20h53.0m	+28°55	–0.5
Feb. 10	20h08.4m	+20°56	0.2	Feb. 25	21h07.1m	+31°09	–0.7
Feb. 13	20h18.1m	+22°47	0.1	Feb. 28	21h22.9m	+33°25	–0.9

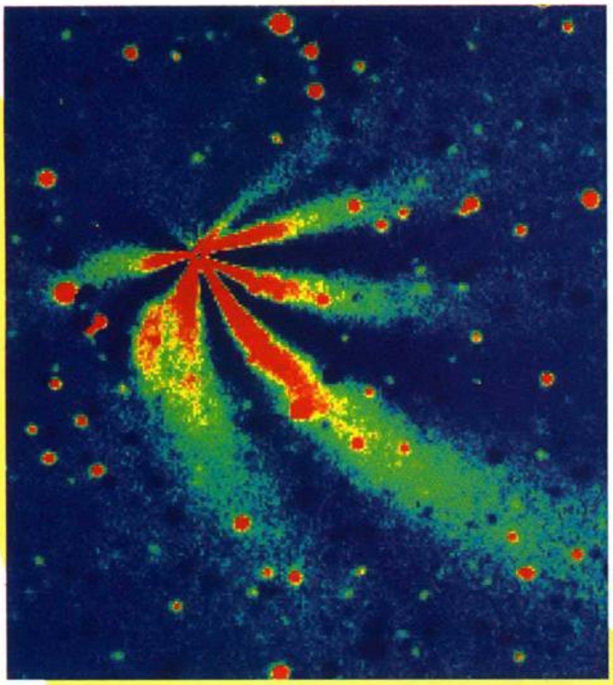
Along with the date, this table provides Comet Hale-Bopp's position in **right ascension** and **declination** (epoch 2000), equivalent to longitude and latitude on the sky. The **magnitude** is a measure of the comet's brightness: the faintest stars visible to the naked eye glow at about magnitude 6, the brightest at about magnitude –1.5. The brighter the comet gets, then, the smaller the number.

month's ASTRONOMY offers an article written by astrophotographer Chris Schur dedicated to capturing this comet on film. In the meantime, try photographing Hale-Bopp with high speed film (1600 to 3200 ISO for color negatives and 1600 for color slides) and a tripod for trailing stars. With the comet in the frame, open a wide-field lens (24mm aperture) one-stop down from wide-open for 40-60 seconds. Be sure to take different exposures using different exposure times and aperture openings. Piggy back on a tracking telescope to create stunning, wide-field images ("Catch a Comet on Film," January 1996).

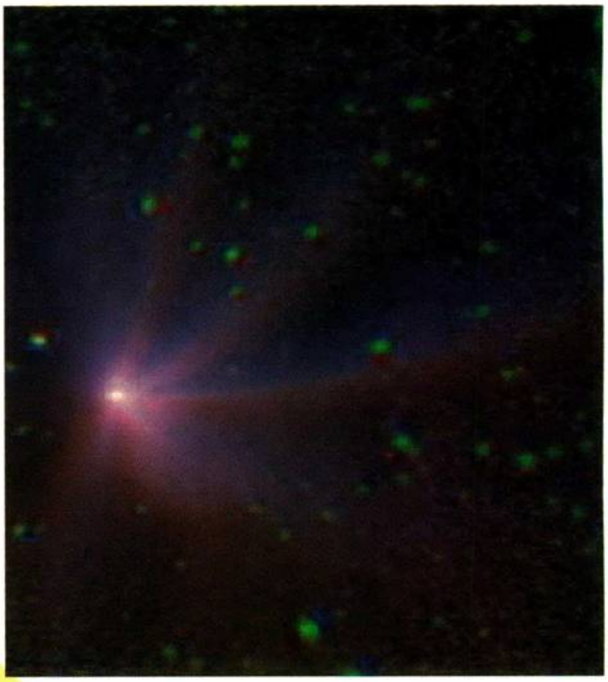
Act One — February

Although beautiful to behold, the Moon's light gets in the way of many astronomical adventures that don't include it. Keep this in mind when planning Hale-Bopp observing treks. Happily, in early February, the Moon's lovely glow will not interfere with comet observing. And February offers the first opportunity of the year to see Hale-Bopp above the horizon in the morning sky. Experts expect the comet to double in brightness by the end of February.

On the 6th, the comet rises around 3:30 local time in Sagitta and has no competition for a couple of hours until a sliver of Moon rises in twilight. Close on the Moon's heels will come Jupiter and Venus, very tightly chasing one another within 1°. See how soon you can spot this group before the Sun rises. New Moon occurs on the 7th. From February 4 to 9, Hale-Bopp passes just southeast of the rich globular cluster M71 (NGC 6838).



Gordon Garradd



Al Kelly and Richard Berry

Peacock-like in appearance, Hale-Bopp's nucleus radiates a fan of jets. The photo at left was taken September 16, 1996, in Australia by Gordon Garradd. Two days earlier, Al Kelly imaged the jets with a Cookbook 245 camera and his 32-inch f/4 Newtonian (right).

Another one of many great photo opportunities provided by this comet will come between February 10th to the 13th when Hale-Bopp passes about 3° southeast of the Dumbbell Nebula (M27). By the 12th, it crosses the border into Vulpecula. On that morning, the comet rises a few hours after the Moon sets. Around the 20th, lovely Luna begins intruding again. By the 22nd, it's in all its glory at full phase and up all night. Take a break from observing Hale-Bopp for a week or so at the end of February while it shares center stage with the Moon.

Act Two — March

The Hale-Bopp Show really kicks in as the comet flies toward its closest approach with Earth on March 22, continuing on to its closest approach with the Sun on April 1. If the optimistic estimates hold up, at magnitude –1.5 to –2.0, it will rival Sirius and Mars as the brightest object in the sky. Even if the estimates are high, Hale-Bopp should be stunning as March progresses — if you shun city lights.

At the beginning of March, the comet is visible in the early morning and in the evening briefly after sunset. On March 5, Hale-Bopp rises just before 3 a.m. and gets no lunar interference for about an hour.

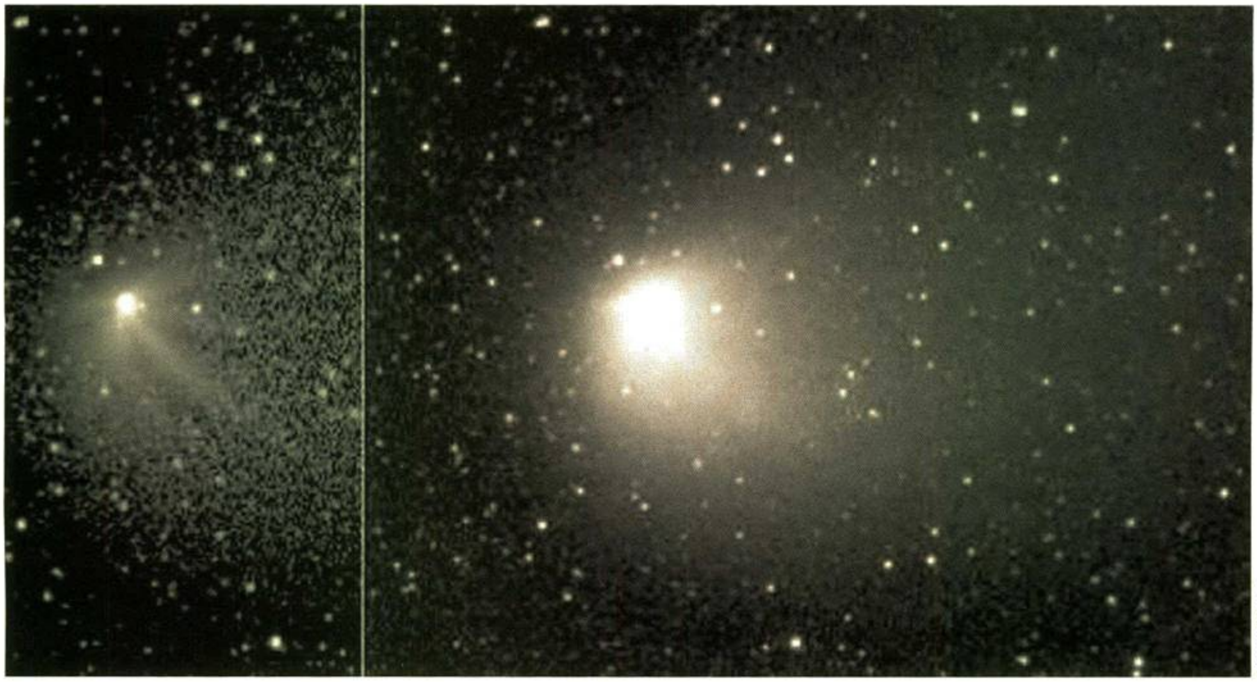
By March 8/9, the Moon is new and no longer limits observations. The comet is well into Lacerta. By the 15th, the comet will be 200 million km from the Sun and 145 million km from Earth. For observers living north of 45° north latitude, the comet will be circumpolar — above the horizon all night long.

For the rest of us, however, keeping moonlight away from Hale-Bopp will be best accomplished in the early morning around St. Patrick's Day, March 17. Having set around 10 p.m., Hale-Bopp will rise again at 2 a.m. and share the sky with the Moon for about an hour. It will cross the border into Andromeda and begin to gain on the Andromeda Galaxy (M31).

Four days from full Moon on the 20th, we can enjoy Hale-Bopp Moon-free for a couple of hours between moonset and sunrise. On March 22, Hale-Bopp reaches its closest approach to Earth, flying headlong to its rendezvous with the Sun. It passes about 3° north of M31 between the 23rd and 28th. Toward the end of March, it reigns supreme in the evening sky.

James Foster

Hale-Bopp skipped through the Scutum star cloud on July 21, 1996, and James Foster closely tracked its movement. He exposed for 60 minutes on Fuji HG400 with a C-11 f/6.3.



Richard Berry

Zooming in on Hale-Bopp, Richard Berry made the image on the right, then enhanced it to show off the comet's detail (left). He imaged for 60 seconds with a Cookbook 245 camera in LDC mode on a 6-inch f/5 Newtonian with a Byers 812 mounting.

On April 1, Comet Hale-Bopp attains perihelion, its closest approach to the Sun.

Act Three — April

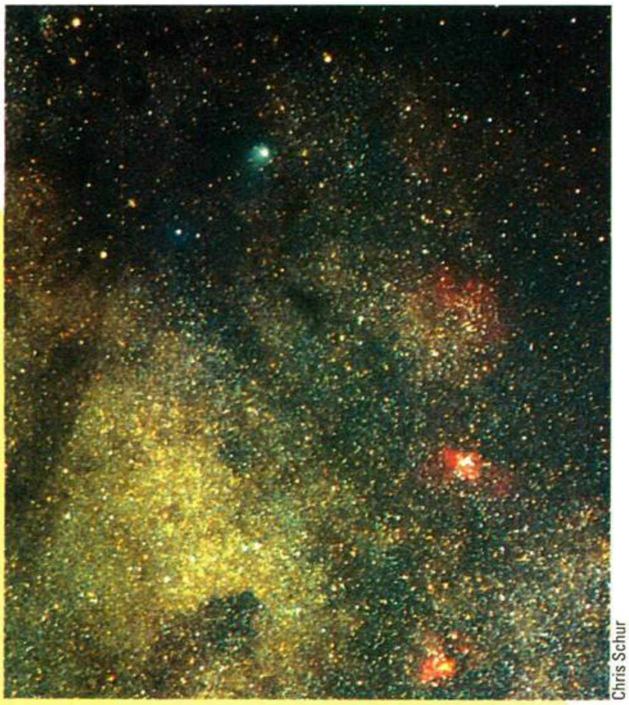
Hale-Bopp is in its glory now — the brightest Earth has seen it in over 4,000 years. If the estimates hold true, it could outshine Sirius (the brightest star in the sky) at a magnitude of –1.5 to –2.0. The comet takes center stage for the first half of the month. And then again, after the Moon bows out of the spotlight during the third week in April, Hale-Bopp returns for a bright, although brief, encore.

Best observed in the evening sky, Hale-Bopp is about 1° from Gamma (γ) Andromedae, a beautiful binary, on April 2. From the 2nd until new Moon on the 7th, Hale-Bopp traverses a galaxy-rich field in Andromeda, practically grazing NGC 891, and then on to seemingly pass through two galaxy clusters beyond. Crossing into Perseus, it barely manages to squeeze to the south of M34 (NGC 1039), a lovely open cluster. The Moon catches up to the comet by the 11th, so we take a break once again until after full Moon on the 22nd. From the 22nd through the 5th of May, Hale-Bopp passes east of the Pleiades cluster in Taurus. By now, the comet has begun to dim and is heading farther and farther south toward Orion, sinking closer to the western horizon. Finally, in mid-May, Comet Hale-Bopp will be lost in the Sun's glare.

During the course of the next few months, ASTRONOMY will keep readers posted with updates, photographs, and anecdotes featuring this hotly anticipated comet. This article begins a three-part series intended to provide you with every opportunity to get the most out of the Hale-Bopp experience.

And, no matter what its brightness and tail length, everyone agrees — Comet Hale-Bopp should put on a stellar performance for its first audience in 4,200 years.

Hale-Bopp shares center stage with M16 and M17 in this photo taken by Chris Schur on July 20, 1996.



Chris Schur

Patti A. Kurtz is assistant editor of ASTRONOMY and has been observing Comet Hale-Bopp since July 29, 1995.

Get a Grip

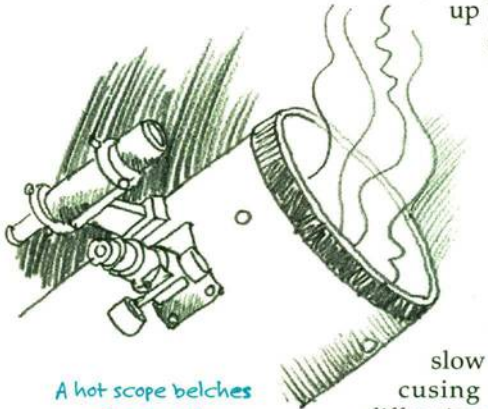
The very air we breathe conspires to ruin our view through a telescope.

You probably think that image quality in a telescope begins when light bends through a lens or bounces off a mirror. Well, think again. Most of the time telescopes don't work at their theoretical limits because of what's called "bad seeing," air turbulence somewhere along a path starlight takes shortly before reaching your eye. This turbulence may lie several thousand feet up in a jet stream or within your telescope as heat currents. Tiny clues will betray which is the case; knowing what causes turbulence lets you avoid it and the bad seeing it causes.

Lowly Turbulence, Lofty Effects

Jupiter's in the eyepiece. The image is doing this slow, undulating crawl around a significant portion of the field of view. Welcome to "slow seeing," caused by turbulence from nearby sources that radiate heat into the cool night air. Because you can isolate and usually eliminate these sources of thermal pollution, slow seeing is easy to combat.

Start by directing attention to the telescope. Let it cool and equilibrate to ambient temperature for at least one hour before observing. Some observers with open tubes, like reflectors, hook up battery-powered fans to speed up the process. Telescopes with closed tubes, like refractors, offer no such option and must wait out the cooling process. This may not be as bad as it sounds; a closed tube won't belch out currents of warm air.

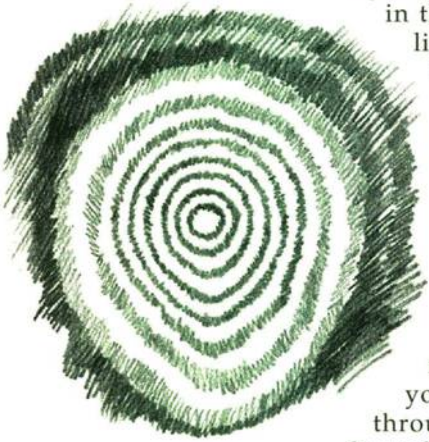


A hot scope belches air currents

Check for this type of slow seeing by slightly defocusing a star's image into its diffraction rings. Look for slow-moving blobs that seem to ooze through zones of the ring pattern. Those are currents of warm air escaping the telescope tube.

Another source of slow seeing may lie in the immediate vicinity of your scope. Make sure nobody's standing near the scope's line of sight. And if you're set up inside an observatory, use a fan to draw the day's heat from the building. Even observatory design comes into play here: A roll-off roof surrenders a building's heat to the open sky more efficiently than a chimney-like slit. Buildings made from wood or sheet metal also have less thermal inertia than those made of concrete block or masonry.

Another remedy for slow seeing might rest in a change of venue. Avoid sighting over things that soak in the Sun all day, like a neighbor's roof or a parking lot. Don't set up inside a depression. Cold air sinks into such pockets during the course of an evening, so it's more likely you'll be looking through a turbulent boundary where cold air meets warmer air. Also, stay away from the edge of a depression; air racing past you on its way to lower ground leads to unsteady seeing.

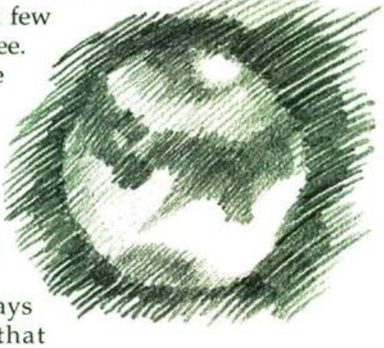


Air currents distort an out-of-focus star

Finally, don't observe too close to the horizon. Many more sources of rising air lie in that direction than, say, 45° up.

Lofty Turbulence, Lowly Effects

High-altitude turbulence arises from eddies only a few inches across that form layer between warm and colder air. All it takes to create a turbulent layer are temperature differences as small as a few hundredths of a degree. These boundaries lie near areas where different types of air meet and blend in our atmosphere: jet streams, cold fronts, and around the edges of clouds.



Typical "Fast" seeing

Such mixing betrays itself in images that quickly churn and boil, but stay put in one area of the field of view. These effects happen very fast, rip-

on Sharper Seeing

Here are clues to detecting the culprits and how to take action.

by John Shibley

pling across an image in a fraction of a second, hence the popular moniker "fast seeing." And although fast seeing is easy enough to detect, there's little to do but anticipate it.

Polar jet dips south in winter

Pay careful attention to where jet streams snake across weather maps. The middle latitudes suffer especially during the winter months, when the polar jet dips south and carries along winter storms. If a jet stream passes over your area, you'll see the effects of high-altitude turbulence. Find out where these streams are by watching the Weather Channel or the weather segment of your local news.

A quick look out a window will also tip you off to fast seeing. Count on plenty of blurry viewing immediately after a cold front passes. While skies may look transparent after a front, they are not that steady; air is still in a state of thermal flux. For steadiest views, wait until the high-pressure system that follows a cold front settles into place.

Also, keep an eye out for approaching warm fronts, marked by high "mare's tail" cirrus clouds. One to three days before a warm front's arrival, southerly winds carry air that is warmer than the surrounding ground. This puts a lid on rising air to yield steadier views.

Finally, avoid observing near the edge of middle-level clouds. Clouds are nothing more than billowing columns of moisture-laden air that punch into a cooler layer of air. There's no shortage of turbulence in the immediate area where this happens. The least likely environment for fast seeing is stagnant, homogeneous air. Believe it or not, some of the steadiest seeing comes on hot, hazy summer evenings.

Bigger Isn't Always Better . . .

Even with this good advice, it's rare you'll avoid bad seeing entirely. Larger scopes are especially sensitive to unsteady nights. Why? Ironically enough, it's because they suffer from better resolving power.

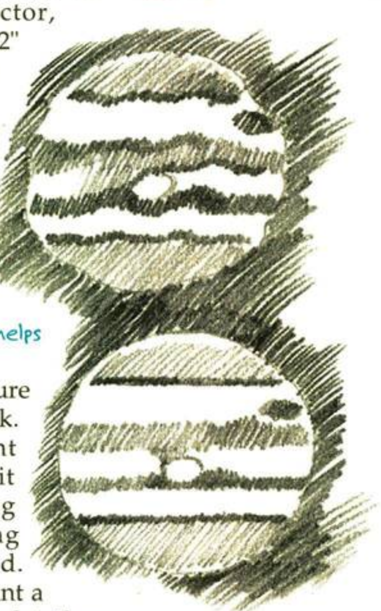
Atmospheric turbulence spreads light over a circle appropriately called a "circle of confusion," measured in seconds of arc. Bigger eddies, the result of a lot of turbulence, create larger circles of confusion that affect a wider range of telescope apertures. As turbulence dies down, the eddies responsible for smearing light get smaller, as do the resulting circles of confusion.

While observers with smaller scopes might perceive an improvement in seeing, those using larger apertures see no change at all. Larger scopes continue to resolve the blurring effects of still-lingering eddies. Consequently, larger scopes are more susceptible to some finer forms of bad seeing.

In a specific example, assume that air turbulence on a certain night creates a 1" circle of confusion. A 10-inch scope capable of resolving detail down to 0.5" sees this turbulence as a rippling, "fast" form of bad seeing. On the other hand, a 60mm refractor, which can only resolve down to 2" reveals a relatively sharp image that occasionally jumps around the field of view. For the most part, smaller aperture scopes only detect coarser, avoidable forms of poor seeing, such as "slow seeing," created by nearby thermal sources.

Knowing this, some observers "beat the seeing" by stopping down a large-aperture telescope with an aperture mask. Although this technique might keep an image from rippling, it won't keep it from jumping around. Besides, most seeing changes from second to second. When it does improve, you'll want a full aperture to glean as much detail as possible, however fleeting.

Before



Stopping down helps

After

This underscores a point worth remembering. Patience is often the most overlooked factor when dealing with bad seeing. Your eye can grab a myriad of detail in just a fraction of a second when seeing clears. Rather than waiting for a night of perfect seeing, keep an eye out for reasonably steady skies and observe as often as possible. This alone will guarantee you many spectacular views for years to come. □

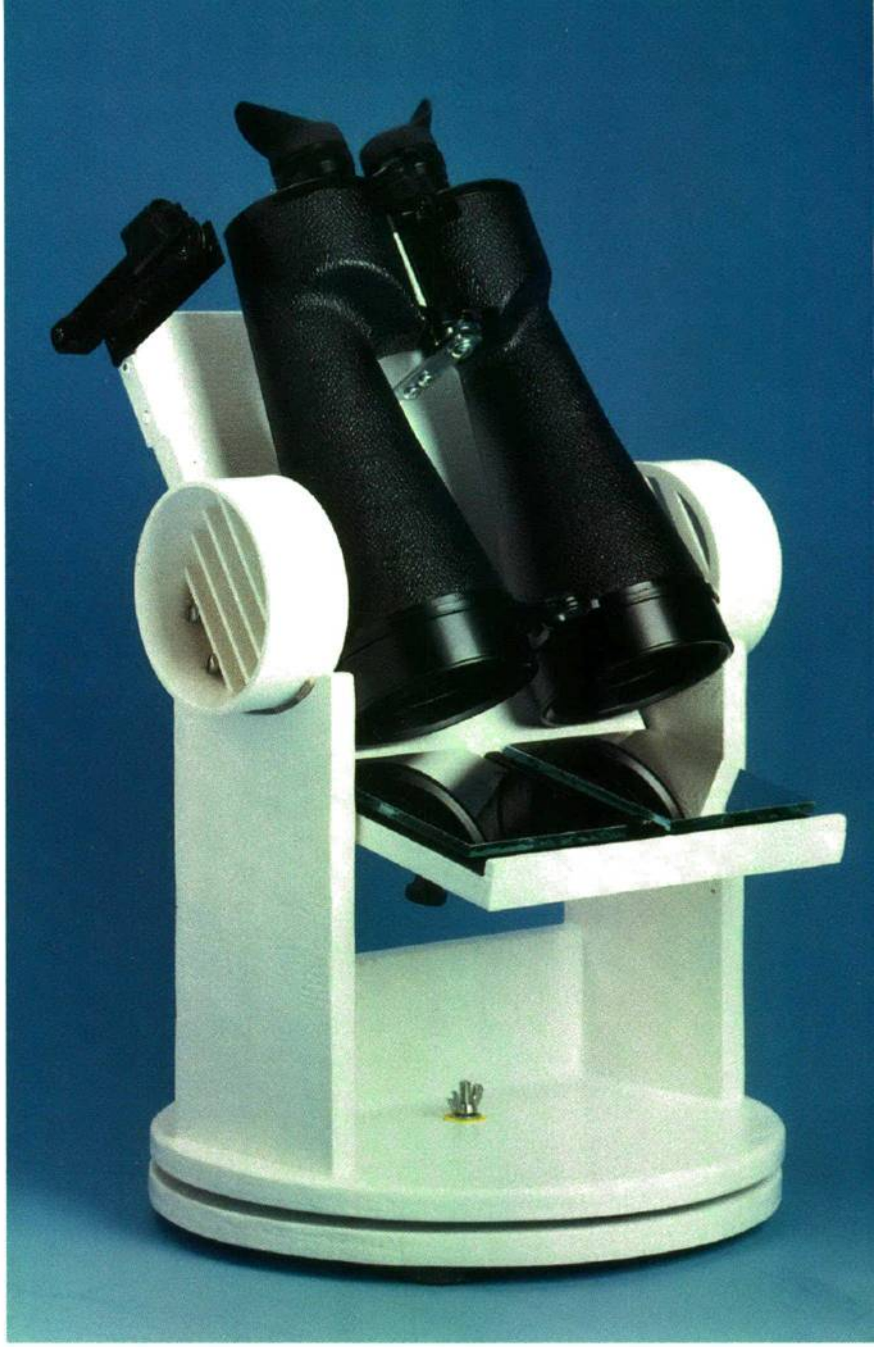
Associate editor John Shibley enjoys lunar and planetary observing during moments of steady seeing.

Illustrations by Bruce Bond

Stabilize Your Bino-Eyes

The Skyscanner bino-holder yields a steadier view of the heavens thanks to a couple of mirrors that reflect the sky into a pair of binoculars.

by David Hudgins



Skyscanner lends a pair of binoculars a heads-up view of the heavens courtesy of two mirrors.

Sparkling starclouds, wispy nebulae, and diamond-like open clusters stream brightly across your binocular field. These are the joyful sights of binocular observing.

But binoculars have a real downside when it comes to comfort. Holding them steady while leaning back to scan the night sky can literally give you a pain in the neck, especially if you observe with high power, "giant" binoculars.

One solution could be the Skyscanner, a portable viewer you can build for less than $50. It uses two mirrors that reflect starlight up into the binoculars for comfortable observing.

Skyscanner can sit on a picnic table or mount to an adjustable photo tripod. For serious observers, the Skyscanner makes ambitious programs like comet hunting and variable star observing easier to undertake, thanks to the steady view it provides.

Mirrors to the Heavens

Skyscanner has two main parts: A binocular and mirror holder designed to fit a particular pair of binoculars, and a rotating base that cradles the holder and points in any direction. You'll want to build the parts in the order we describe to assure everything fits together smoothly.

Skyscanner's key feature is its set of mirrors. They reflect the sky into your binoculars so you can observe easily. Because you'll be observing at fairly low power with a small aperture, inexpensive mirrors made from float glass will work quite well. Such mirrors are available from suppliers such as Edmund Scientific for $10 to $15 each. For best results, make sure the mirrors are at least 5mm thick. With high-power binoculars (such as the 20x80 models) you can expect just a bit of image softening.

To assure that each mirror captures enough sky, select a width slightly larger than the binocular's front lens diameter. The mirror length should also be at least 1½ times the diameter of the objective lens.

Both mirrors fit into the binocular/mirror holder you'll build first. But before starting, make a scale drawing that shows the holder from the top and one side. This will help you figure its proper dimensions so that everything fits together properly.

The holder should only be a ¼-inch wider than the binoculars to keep the Skyscanner as compact as possible. Make sure the base plate under the binoculars extends ¾ inches in front of the lenses. This will allow adequate space to attach the angled mirror plate and accommodate the width of the mirrors.

Make the Mirror Holder

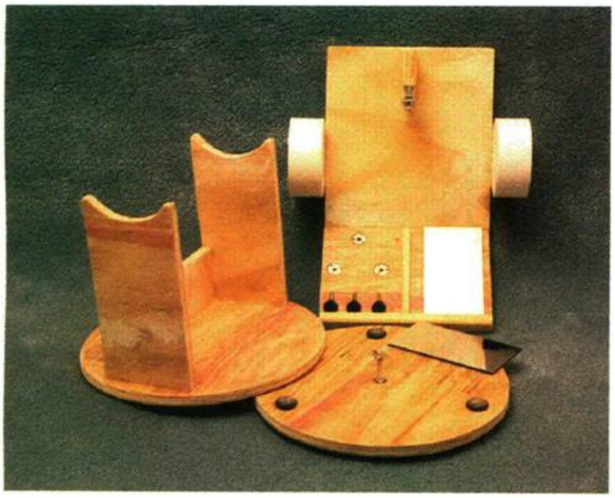
Except for the mirrors, the Skyscanner's parts come from any hardware or home supply store. All components are ⅝-inch A/C plywood and assemble with wood glue and screws.

Fashion the mirror holder based on your scale drawing. This has two components: a plate to hold the binoculars and a support that accommodates the mirrors. The binocular plate typically measures from about 5 inches by 6½ inches for 35mm binoculars to 10 inches by 9 inches for 80mm units. Make the mirror support's length ¾" greater than the long dimension of your mirrors to leave room for a cover. It should be cut and glued into place at a 135° angle to the binocular plate.

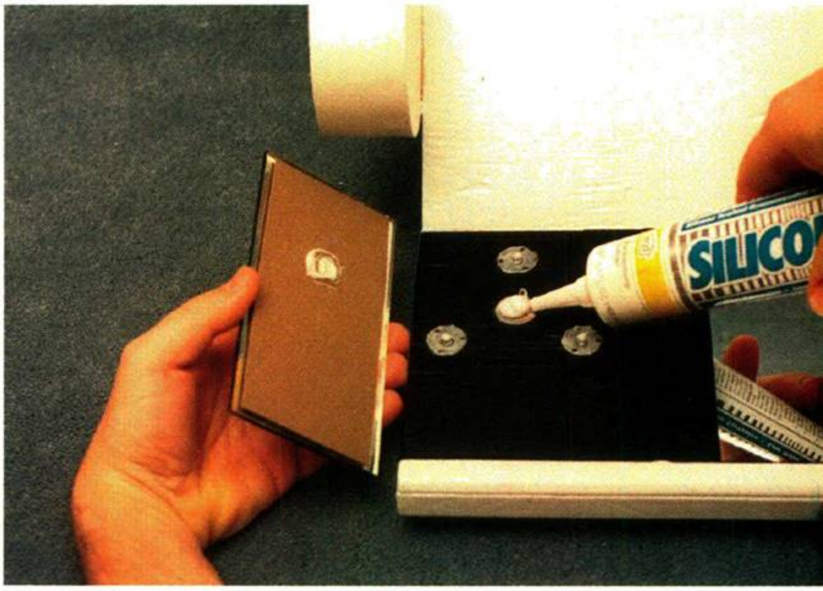
After gluing these two components together, move on to the binocular mounting post. Make the vee-grooved post from plywood and glue it to the plate that holds the binoculars. Install a 2½" hardware patch on the grooved post. The binoculars will affix to this patch plate with a small screw.

All that's left to do now is to install the mirrors. Center each mirror in front of a each of the binocular's objective lenses. Position them on the mirror support so they fully illuminate each lens. Do this by attaching your binoculars to its vee-grooved mounting post.

The Skyscanner binocular mount has three main components: a binocular and mirror holder (right) that rides on a base (left), which in turn fits on a round platform (center).



All photos by the author



The mirrors attach with a dab of silicone. Note the three adjustment screws that allow you to get rid of double images.

From about a foot away, sight into the binoculars and position the mirrors until they create a circular-looking exit pupil. Now trace around each mirror as a guide to later gluing.

The surfaces of both mirrors must also be exactly parallel to avoid double images. Three adjustment screws under one mirror makes alignment easy at the start of each observing session. Locate the center of one mirror on the plywood mirror plate and mark the spot. Use a protractor to mark the location of three holes for the three screws. Place the holes 120° apart at a radius of 1 to 1½", depending on mirror size.

Drill holes and glue three tee nuts to the top of the mirror plate. Thread in three screws through the back of the mirror plate, leaving them flush with the top of the tee nuts. These adjustment screws will tweak the mirror's tilt.

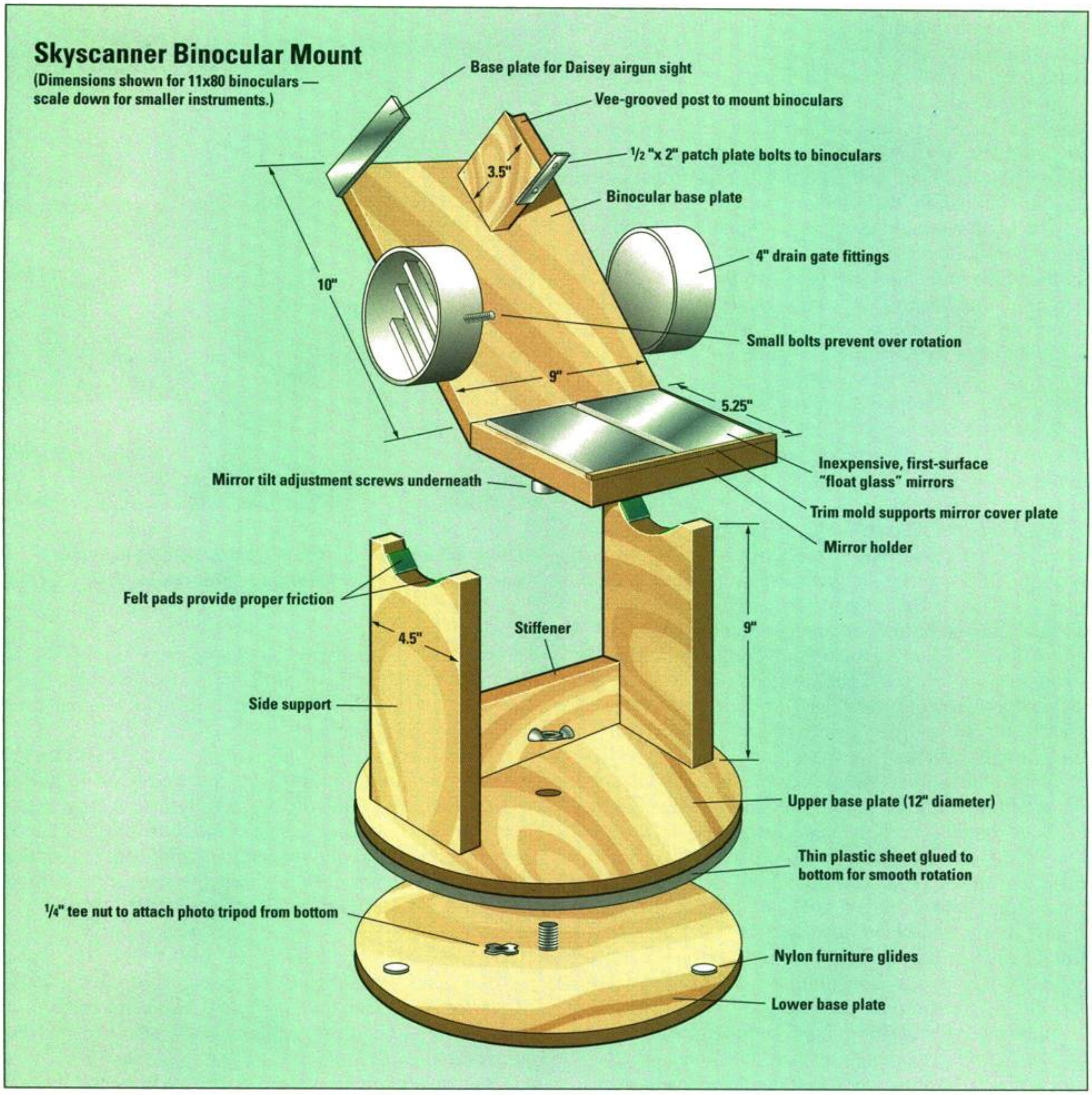
You might notice that the mirror surfaces are exposed in this design. Protect them by building a cover plate. A little trim molding glued to the mirror support should hold a cover firmly over the mirrors without touching them.

On To the Bearings

After sanding the binocular/mirror holder, it's time to attach two PVC drain gate fittings that will serve as altitude bearings. Their location is very important to the Skyscanner's balance.

To find where to put them, temporarily mount the binoculars and mirrors on their respective plates, then balance the mirror holder on a pencil along the holder's long dimension. Mark the balance point on each side of the holder.

Fasten the PVC fittings with two long wood screws. Don't make the mistake of mounting the fittings through their centers. They must be mounted near the bottom so the axis of rotation lies near the mirror holder's center of gravity. Finally, install two small



Skyscanner Binocular Mount

(Dimensions shown for 11x80 binoculars — scale down for smaller instruments.)

Base plate for Daisey airgun sight
Vee-grooved post to mount binoculars
½"x 2" patch plate bolts to binoculars
3.5"
Binocular base plate
10"
4" drain gate fittings
Small bolts prevent over rotation
9"
5.25"
Inexpensive, first-surface "float glass" mirrors
Mirror tilt adjustment screws underneath
Trim mold supports mirror cover plate
Mirror holder
Felt pads provide proper friction
4.5"
Stiffener
9"
Side support
Upper base plate (12" diameter)
Thin plastic sheet glued to bottom for smooth rotation
¼" tee nut to attach photo tripod from bottom
Nylon furniture glides
Lower base plate

Skyscanner Materials Table

(2) First Surface Mirrors
(Suggested supplier: Edmund Scientific; 609-573-6295)

- 35mm to 50mm binoculars 51mm by 76mm mirrors, Edmund item number J40,040.
- 80mm binoculars use 98mm by 113mm mirrors, Edmund item number J43,048.

⅝-inch A/C exterior plywood (about six square feet)

(2) 4-inch PVC drain gate fittings
(1) Daisey Model 809 Electronic Point Sight

HARDWARE

(5) ¾"-diameter nylon chair glides
(4) ¾"-diameter self-adhesive felt pads
(8) 2" #8-24 wood screws
(1) 2" x ¼" bolt, nuts, washers, wing nut
(1) 2" mending plate (to attach binocs)
(3) #8-½" tee nuts and #8-1" screws (for mirror tilt adjustments)
(1) ¼"- ½" tee nut (tripod socket)

MISCELLANEOUS

Waterproof wood glue
Silicone tub and tile caulk
Contact cement
Gloss latex enamel paint

nylon furniture glides where the mirror holder might rub against supports from the base.

Finally, it's time to install the mirrors. Before mounting them permanently, use double-stick tape to apply a thin cardboard backing to the back of each. First mount the left, non-adjustable mirror. Put several small dabs of silicone caulk around the edge of the cardboard backing. Now position the mirror on the support using the markings you made earlier. Press the mirror gently into place.

Now install the adjustable mirror. Center a single, 3⁄16" glob of silicone between the three adjustment screws. This glob will serve as a the mirror's pivot point. Use the markings you made earlier when placing the mirror squarely on its support. Set everything aside to dry.

The Rotating Base

Now it's time to move to Skyscanner's base. First make a rough drawing based on the finished mirror/binocular holder. Precisely place the location of the holder's PVC fitting on your drawing. Side supports that cradle the mirror/binocular holder should be about a quarter of an inch wider to allow everything to swing freely. The side supports should also be tall enough to let the binoculars and mirror unit rotate to a vertical position for viewing things close to the horizon. Shorter side supports will sacrifice low-elevation views.

When it comes to the diameter of the base's two circular bottom plates, use your judgment. This can range from 9 inches for small binoculars, to 12 inches for 80mm instruments.

Install three nylon furniture glides on the top surface of the lower base plate. For a smooth contact surface, cover the upper plate's bottom surface with a thin (1⁄16") plastic material. Readily-available plastic "For Sale" signs work well.

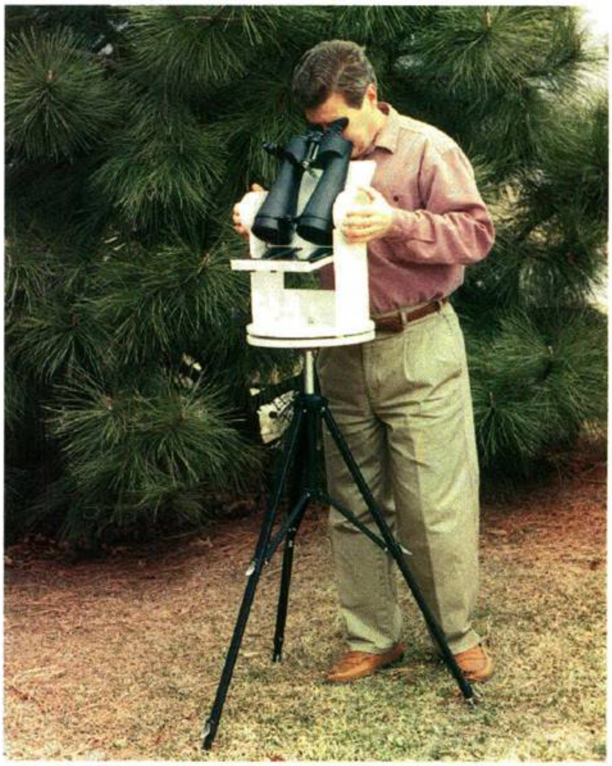
Now attach the side support boards and a stiffener to the upper base plate with screws and wood glue. Drill a 1⁄4-inch hole through both base plates and slip in a 1⁄4" x 2" bolt to act as a rotation axis.

If you plan to mount Skyscanner on a photo tripod, drill a hole through the lower base plate and set a 1⁄4" tee nut into the underside through the top of the plate. Finally, attach three rubber furniture feet to the underside of the lower base plate.

After sanding and painting, adhere four small felt pads to the base unit so they support the rotating mirror unit. Mount the binoculars and set the mirror unit on the rotating base. The felt pads should provide enough friction so that the mirror unit rotates easily up and down.

Which Way to the Sky?

Pointing the Skyscanner is a lot easier if you install some sort of sighting device. For conventional 7 to 10 power binoculars, a simple sight made with two machine screws may suffice. A better solution, especially for higher power binoculars, is a $15 BB airgun sight. This sight appears to project a bright red dot in the sky. You can reduce the LED's brightness by covering half of it with black paint.



One option is to set a 1⁄4" tee nut into the Skyscanner's swivel base mount so it can mount to any heavy-duty photo tripod.

When you do get that first look through the Skyscanner, don't be surprised if it's a tangle of double images. Gently turn each of the three mirror adjustment screws until the images merge. You will need to make this little adjustment at the start of each observing session. The process becomes easier with a little practice.

Scan around the sky. Notice how comfortably you can observe the stars high overhead. This was almost impossible to do with hand-held binoculars. Views are now rock-steady wherever you point the viewer.

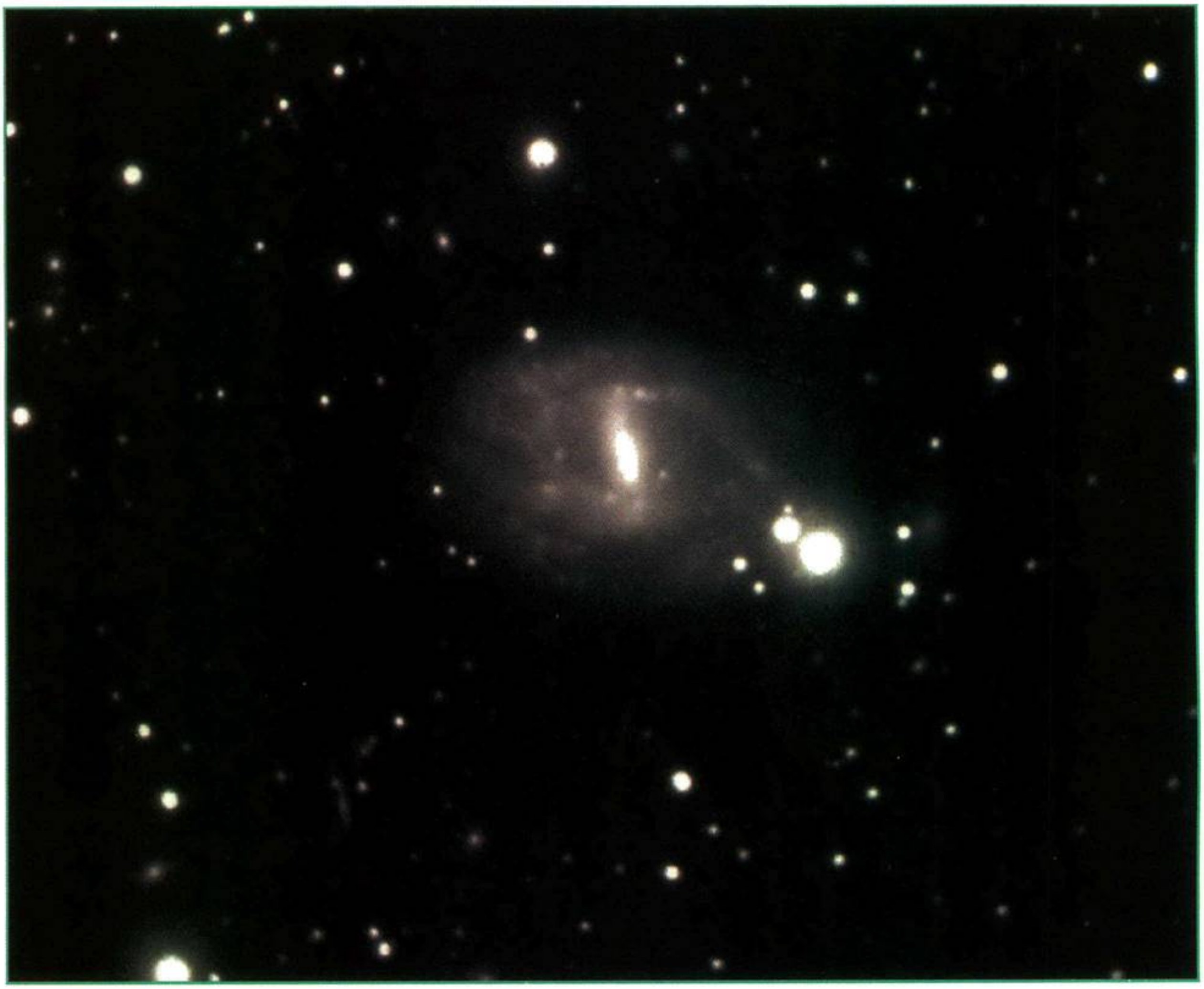
One important point to keep in mind while using the Skyscanner is that objects in it will appear reversed. Some observers adapt to this by looking at star charts with a small mirror. The reflected image matches the binocular view.

This is a tiny inconvenience when you consider the new vistas a Skyscanner opens up. It will become your "telescope" of choice on family vacations. Its table-top user-friendliness will let your family embark on impromptu tours of the Milky Way or monitor the nightly changes of Jupiter's four largest moons, something nearly impossible to do with jiggly binoculars.

After everyone files past for a view, the real fun begins. What discoveries await you in a sky steadied by Skyscanner? ☐

David Hudgins is an engineer who observes with the Astronomical Society of Kansas City. E-mail him at 73602.767@CompuServe.com with any Skyscanner questions or comments.

In Search of Faint



NGC 7741 in Pegasus

When astroimagers first use a CCD camera, they usually point it at some of the old familiar objects. Let's face it, folks, the Whirlpool Galaxy and the Ring Nebula are dying of overexposure. After I imaged a few of the standbys with my CCD camera, I began exploring some galaxies off the beaten path. Thousands of distant island universes are within range of backyard scopes fitted with CCD cameras. Why stick to the same few dozen? I offer the following as an inspiration to my CCD imaging colleagues who could follow the path of galaxies I've imaged (and perhaps do it better), or concoct their own lists with an almost unlimited number of variations. On top of the thrill and adventure of imaging and seeing new objects, formerly uncharted in your own astronomy career, I know that ASTRONOMY readers would be delighted to see images of different and challenging targets.

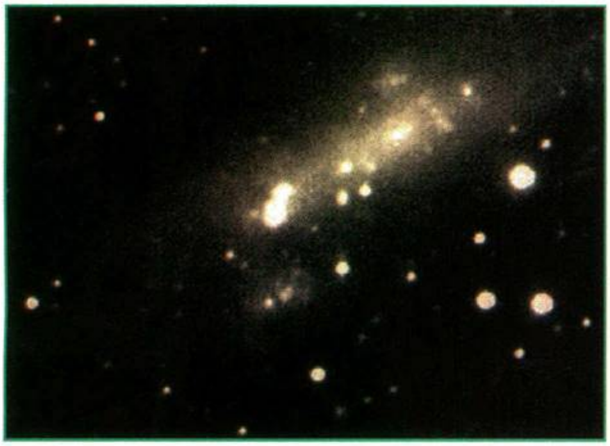
All of the images presented here were taken from the Oregon Star Party site in the Ochoco Mountains of eastern Oregon. Although CCD technology allows you to "subtract" some light pollution, with these faint galaxies there's no substitute for really dark skies.

Before we travel through my itinerary of targets,

Galaxies

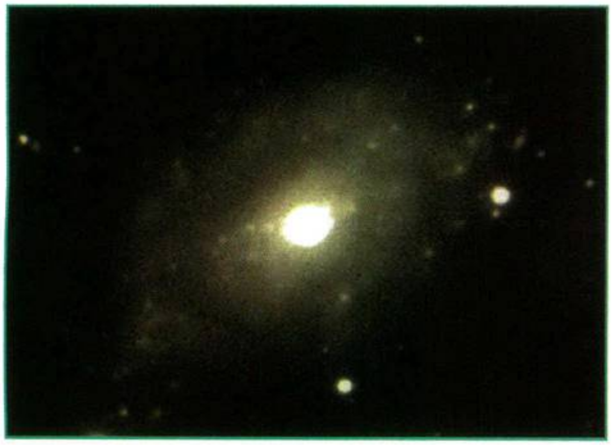
Got a CCD camera focused on galaxies? Hit the road less traveled to capture some obscure gems.

Text and images by William A. McLaughlin



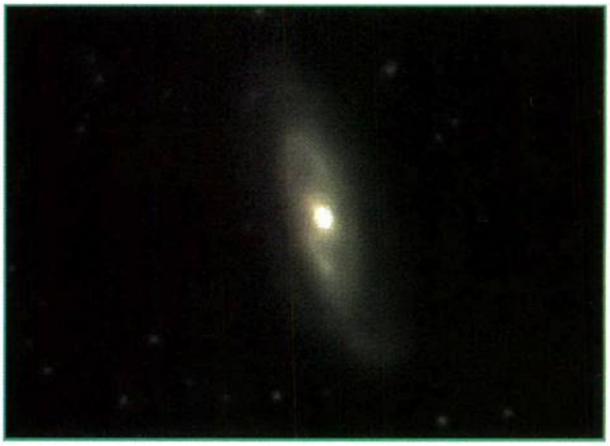
NGC 2366 in Camelopardalis

let me describe the setup I've used for the images reproduced in this article. My telescope is an 8-inch Schmidt-Cassegrain at f/6.3, affixed firmly on a Celestron-Losmandy G-11 mount, and the imaging camera is an SBIG ST-7. To collect the images, I used a Toshiba T1950CT laptop computer that runs SBIG's CCDOPS software. I processed the images using Axiom Research's MIRA A/P and Aldus Photostyler.



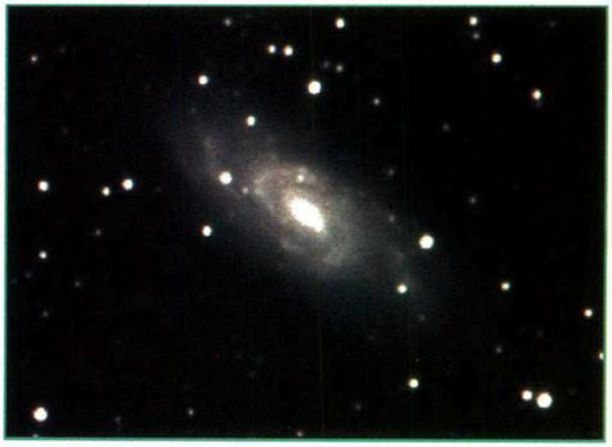
NGC 5448 in Ursa Major

Once I got the setup operating, what amazed me was that a multitude of galaxies looked really interesting. All of a sudden the faint, "average joe" NGC galaxies — the ones that look like a smudge in the eyepiece of a medium-sized scope — show detail in the final CCD frames. I began my search nearly due west of M81, the bright spiral in Ursa Major, which I skipped. Instead, I went to nearby Camelopardalis to find **NGC 2366**, a large, odd-shaped irregular galaxy. Glowing at magnitude 10.9 and measuring 7.6' by 3.5', this galaxy makes a good target for a medium-sized CCD chip such as the KAF400 used in the ST-7. Next, I targeted **NGC 5448**, a 12th-magnitude Sb-type spiral located just east of the bright star Alkaid at the tail of Ursa Major, close to the Bootes border. This galaxy impressed me with its brilliant, pinpoint nucleus and the faint oval cloud of light from its spiral arms. Also in Ursa Major is **NGC 5585**, northeast of M101 and close to the Draco border. This magnitude 10.9 S-type galaxy measures 5.5' by 3.7' and has a bright center surrounded by what appears to be a mottled haze. Two extraordinary edge-on galaxies of the spring sky are **NGC 5529** in Bootes and **NGC 5965** in Draco.



NGC 5585 in Ursa Major

After shooting a few of these galaxies I found that they require pretty long exposure times. Most of the images presented here have exposure times of 40 or 60 minutes and are the sum of either two 20- or two 30-minute exposures. At this pace, I'm happy to get two



NGC 6118 in Serpens Caput

NGC 697 in Aries

or three objects per night. When imaging these galaxies, it's essential to use a well-guided system. Only then can you expose long enough and come away with perfectly round stars. Fortunately, the ST-7 is a self-guiding camera. With this camera and a good telescope drive, exposures of over an hour are possible. Not only does the system give me satisfying results, but it frees me to grab a cup of hot cider.

Afterward, I made the broad transition of turning my attention to the autumn sky. There, as with the spring sky, a huge clump of faint galaxies resides. In Aquarius I imaged **NGC 7606**, a classic Sb-type spiral with a magnitude of 10.8. Although similar in brightness to NGC 2366, this galaxy appears much brighter due to the concentrated hub and high surface brightness arms. It measures 5.8' by 2.6'. Nearby, in Pegasus, you may find **NGC 7741** near the top center of the Great Square of Pegasus. A beautiful barred spiral, it required four 15-minute exposures to avoid blooming caused by a 9th-magnitude star located just to the north. Close examination of this frame reveals several other faint galaxies in the background.

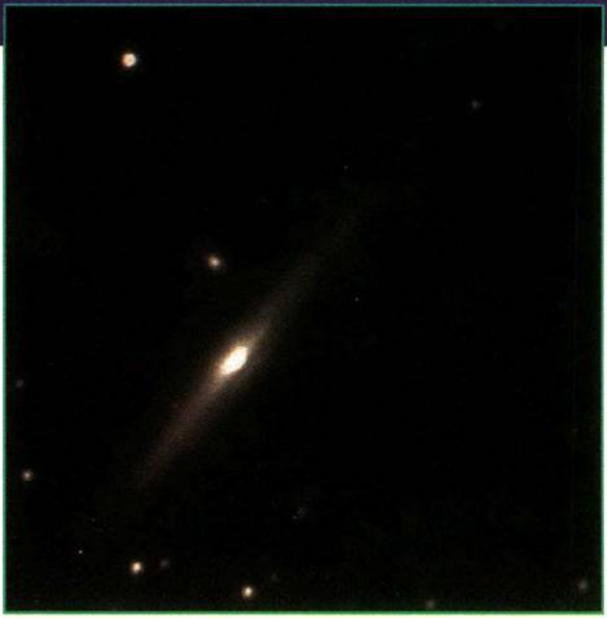
Located in the constellation Serpens Caput, within the "circle" of bright stars that includes a part of Ophiuchus, is **NGC 6118**. This classic Sb-type spiral glows at magnitude 12.3 and spans a mere 4.7' by 2.3'. It shows slightly more detail than NGC 7606, revealing more pronounced spiral arms. With a cup of cider in hand, I downloaded one of the more unusual galaxies in my collection of relative unknowns, **NGC 7640**.

NGC 784 in Triangulum

NGC 507 in Pisces

This large barred spiral in Andromeda appears almost edge-on to us but displays just enough of its face to show its barred nature. It's quite bright, at magnitude 10.9, and spans 10.7' by 2.5'.

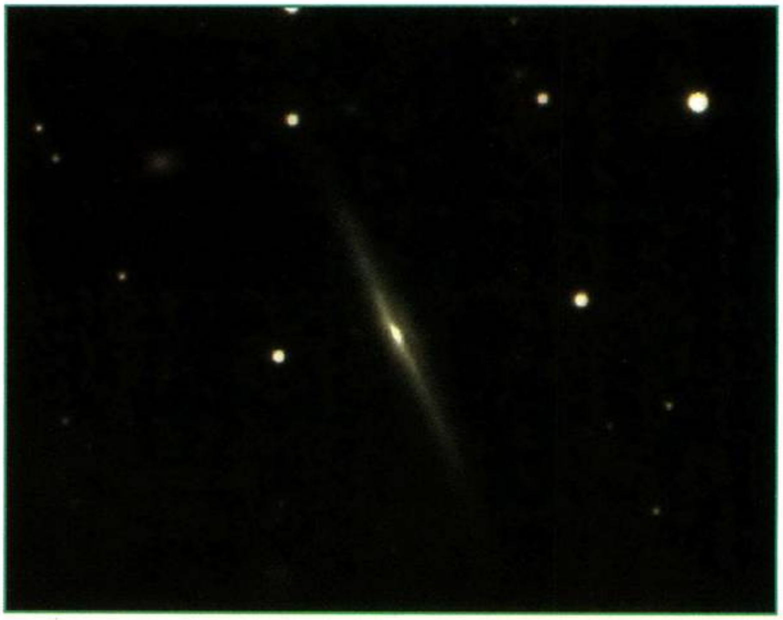
Located just north of Beta Arietis was my final object, **NGC 697**. This somewhat distorted 13th-magnitude barred spiral measures 4.7' by 1.8' across. This galaxy appears deformed in that one end seems normal but the other has an extension that looks like a warped spiral arm. **NGC 507** in Pisces and **NGC 784** in Triangulum contrast strongly with this object. NGC 507 is an 11th-magnitude lenticular galaxy lying in the center of a cluster; NGC 784 is a barred spiral appearing edge-on to our line of sight.



NGC 5529 in Bootes

The most beautiful thing about going after little-known galaxies is the nearly inexhaustible supply. Thousands of candidates out there are just waiting to be picked off by the ever-increasing number of CCD imagers. True, they may not be as spectacular as the Whirlpool, and they are certainly more difficult to image, but to go where few imagers have gone before carries its own excitement. You never know what is going to light up the screen when you download the next image. □

William McLaughlin is an avid astroimager who lives in North Bend, Oregon. He writes a column for the Rose City Astronomers' newsletter, the Rosette Gazette.

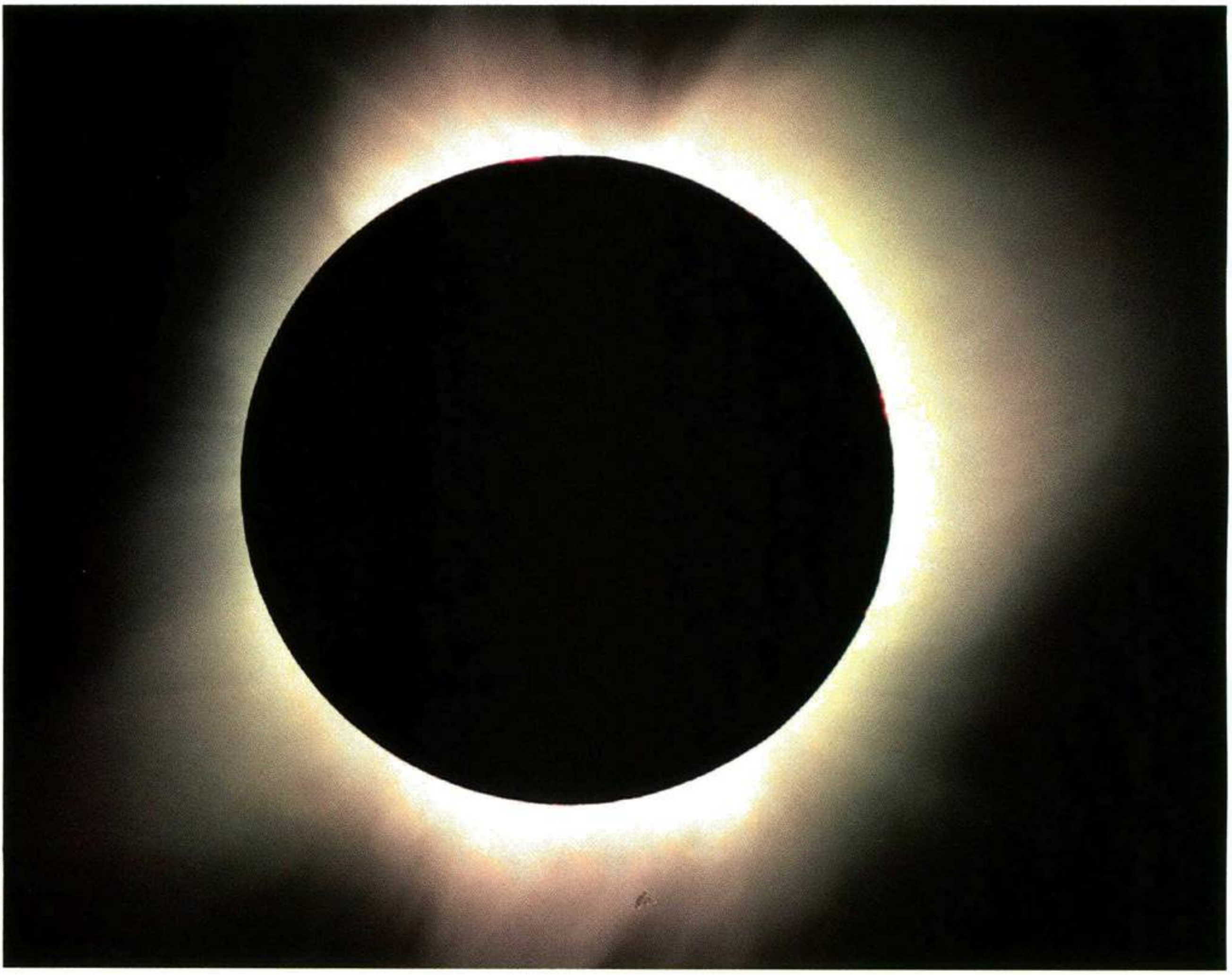


NGC 5965 in Draco

COLLECTING THIS CENTURY'S LAST ECLIPSES

A trio of total eclipses ends the 20th century. Chasing each one will take you to the steppes of Mongolia, the beaches of the Caribbean, and the historic cities of Europe.

by Alan Dyer



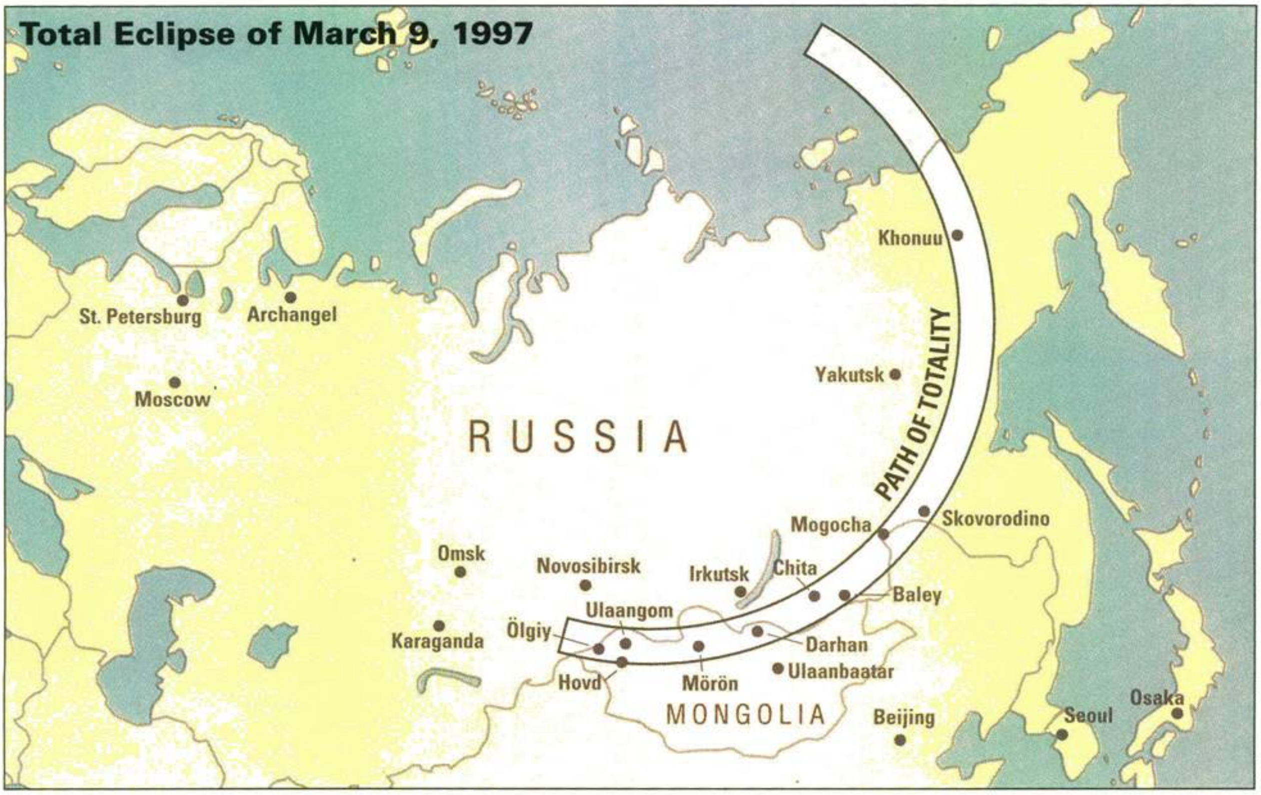
Roland and Marjorie Christen

Astronomy is a hobby of collecting. It's rarely described that way, but consider it for a moment. True, we don't collect stamps, coins, antiques — anything material. What we do collect are experiences: a dark night sky, a meteor shower, the view of an elusive galaxy, an eclipse.

On a scale of 1 to 10, with 10 being the rarest and most spectacular astronomical sight we can experience, a total eclipse of the Sun must surely rate a perfect 10. No life list of astronomical experiences is complete without the adventure of standing in the Moon's shadow watching the Sun disappear from the daytime sky.

Perhaps you missed the spate of solar eclipses that crossed North America in the 1970s, the exotic locale eclipses of the 1980s, or the Big One of 1991. Or per-

The 1990s provide three more chances to view the Sun's corona. Although none offers the nearly seven minutes of totality seen in July 1991 (above), the combined lengths total over nine minutes.



All diagrams by ASTRONOMY: Elisabeth Rowan

Choose Your Site

March 9, 1997

Location	Duration of Totality	UT at Maximum Eclipse	Sun's Altitude	Sun's Azimuth	Average Cloud Cover
Mongolia					
Darhan	2m24s	0:50:07	13°	113°	50%
Hovd	1m02s	0:41:49	3°	100°	40%
Mörön	2m11s	0:47:27	9°	108°	40%
Ölgiy	1m56s	0:42:53	2°	98°	40%
Ulaangom	1m49s	0:45:03	4°	101°	40%
Russia					
Baley	2m38s	1:01:26	19°	125°	50%
Chita	2m15s	0:59:42	17°	122°	50%
Khonuu	1m53s	1:43:49	18°	166°	20%
Mogocha	2m32s	1:07:39	20°	130°	50%
Skovorodino	2m41s	1:11:54	22°	135°	50%

haps you've already chased the Moon's shadow to collect precious moments of umbral time and hope to add to your collection. First-timer or veteran, you have three more chances this century to collect a total eclipse experience.

Eclipse in Asia: March 1997

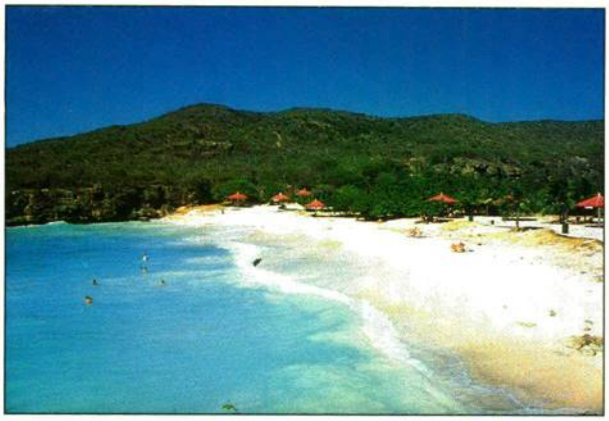
Any eclipse trip is an adventure. Being in just the right spot in the narrow path of totality at just the right time — and under clear skies — takes months of planning, then the willingness to dump those plans at the last minute when the weather refuses to do what statistics said it should. Every eclipse poses such risks. But for this year's eclipse, the adventure factor is high.

On March 9, the Sun will disappear over the snowy steppes of northern Mongolia and eastern Siberia. Mongolia in March? Hardly the stuff of dream vacations — except for addicted umbraphiles. A unique attraction of this eclipse is that during the 2 minutes and 25 seconds of totality in northern Mongolia, Comet Hale-Bopp will appear in the darkened sky. Not since the discovery of a comet on November 1, 1948, has a bright comet been visible in an eclipse sky. In early March, Hale-Bopp might be glowing at zero magnitude some 40° straight above the Sun, with a ghostly tail pointing away from the solar corona.

The good news is that the chance of clear skies in the prime viewing area north of Ulaanbaatar, the capitol of Mongolia, is about 50 percent, pretty good by eclipse standards. The centerline is accessible from the capitol by road and rail.

The bad news is that in early March, just as on the interior plains of North America, clear skies usually come with Arctic air. March temperatures in Mongolia can drop to –40°, with conditions well below freezing a near certainty. The Sun will be only 13° above the southeastern horizon in this morning eclipse.

Not so coincidentally, the last cold-weather eclipse most shadow chasers will remember took place 18 years, or one saros cycle, before this one. The total eclipse of February 26, 1979, the last in Canada and the United States until 2008, is the previous member of Saros 120, the family of eclipses that contains the 1997 event. If cold-weather eclipses are to your liking, this saros delivers: The next in Saros 120 crosses the North Atlantic in March 2015.

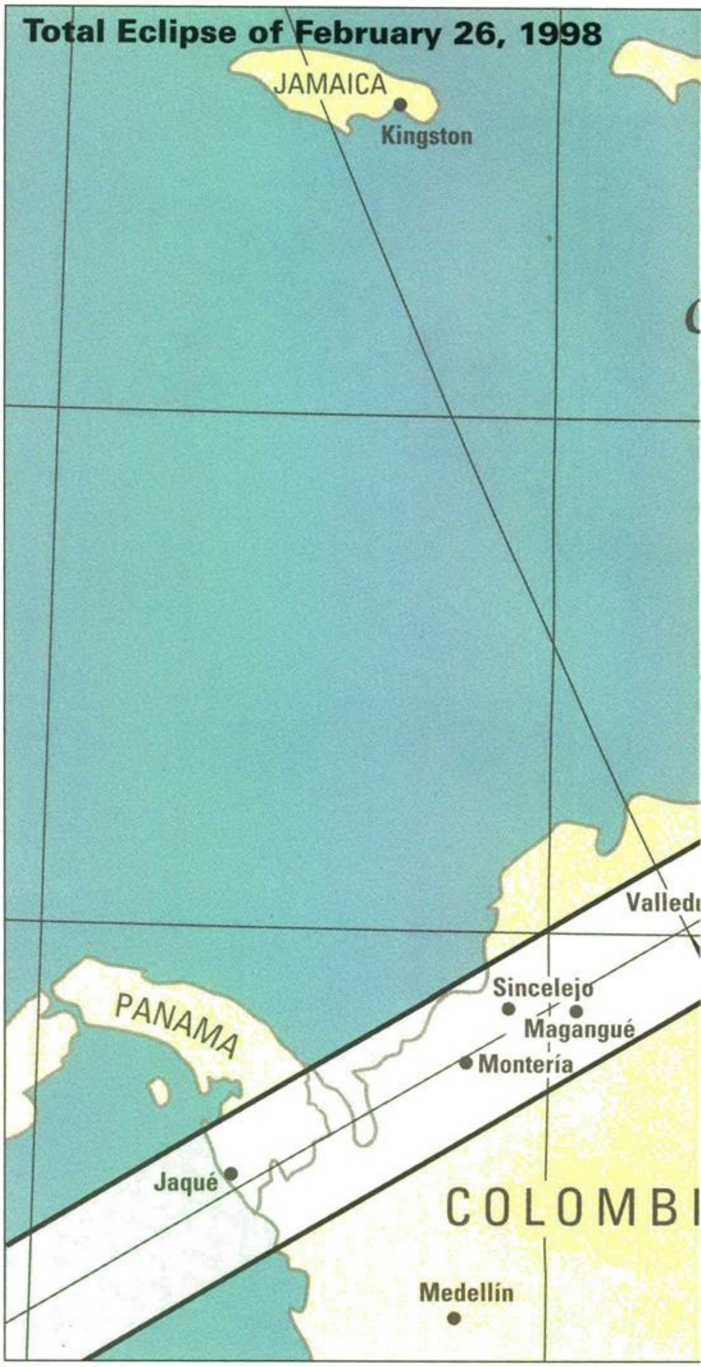

Alan Dyer

In February 1998, you can be sure the warm beaches of the Caribbean will entice many northerners tired of the long winter.

Choose Your Site

February 26, 1998

Location	Duration of Totality	UT at Maximum Eclipse	Sun's Altitude	Sun's Azimuth	Average Cloud Cover
The Caribbean					
Oranjestad	3m06s	18:11:21	61°	224°	40%
Plymouth	2m57s	18:31:26	49°	234°	50%
Pointe-à-Pitre	2m12s	18:32:20	49°	235°	50%
St. John's	2m05s	18:32:25	48°	234°	50%
Willemstad	1m58s	18:13:22	60°	226°	40%
Colombia					
Magangué	3m56s	17:55:57	69°	212°	50%
Montería	3m58s	17:52:26	70°	208°	50%
Sincelejo	3m32s	17:54:23	70°	209°	50%
Valledupar	3m39s	18:01:18	66°	216°	50%
Panama					
Jaqué	3m56s	17:44:45	73°	197°	50%
Venezuela					
Maracaibo	2m50s	18:05:28	65°	221°	40%
Punto Fijo	3m27s	18:09:59	62°	224°	40%



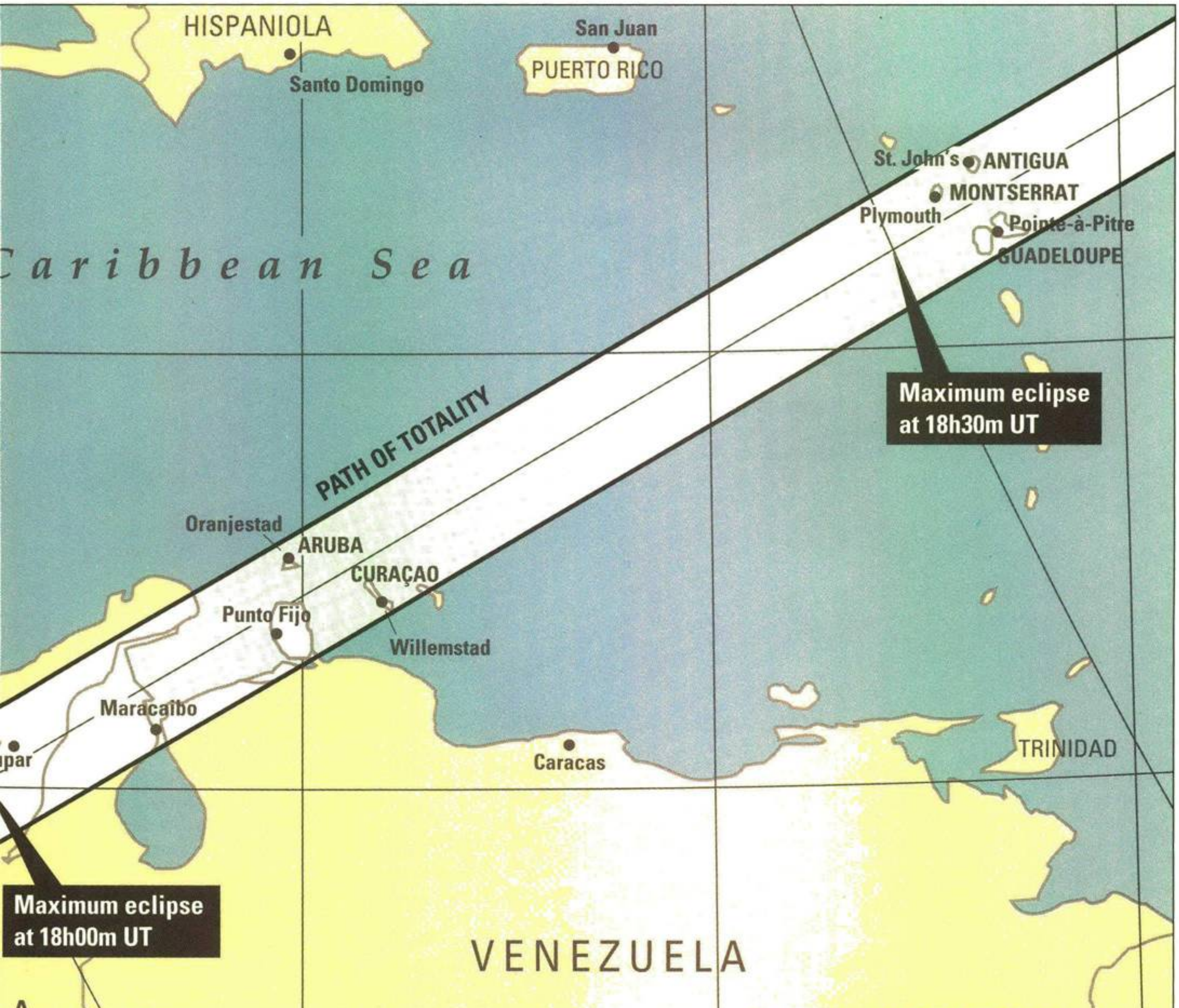
Eclipse in South America: February 1998

If we could design eclipses to order, we'd be hard-pressed to create a better one than this. On February 26, 1998, the Moon's shadow crosses the Galápagos, the northern tip of South America, and then the southern Caribbean. The Caribbean in February? This is the stuff of vacation dreams! Quite a contrast to 1997.

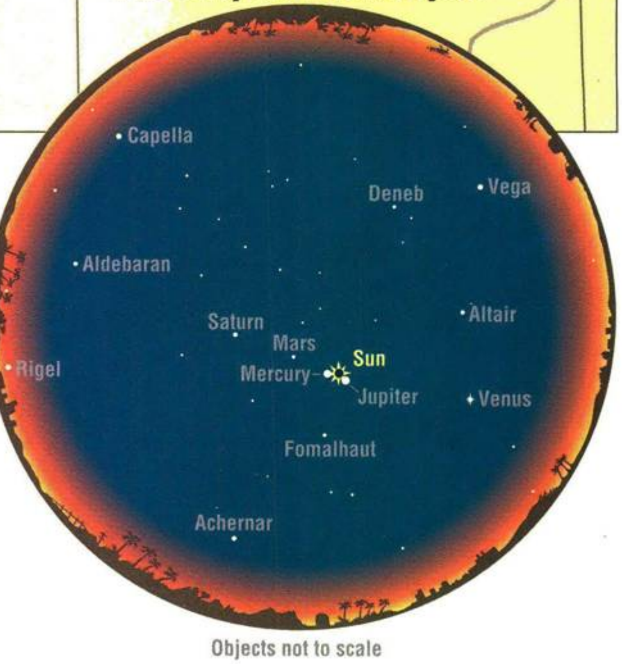
Not since the 7-minute eclipse of July 1991 has an eclipse generated so much interest. Imagine escaping winter's blast to bask in the Caribbean Sun, then watching that very Sun disappear for almost four minutes. And this from a white sand beach or the deck of a luxury cruise ship. Then at night, gazing at the winter sky in absolute comfort with Orion overhead and the Southern Cross rising.

Eclipse chasers have several options for a destination, each with unique advantages. Over the Galápagos Islands, totality lasts almost 4 minutes, only 9 seconds shy of the maximum for this eclipse. Clear-sky chances are about 45 percent. However, the path of totality misses the main tourist-accessible islands of the Galápagos. The small northern islands the path does cross are restricted reserves, so eclipse viewing will most likely be from sea.

At its next landfall over Panama and Colombia, the shadow crosses the infamous, and cloudy, swamps of the Darien Gap. But farther along the path on the plains of eastern Colombia, the Sun shines on average for nearly 80 percent of the day in February. Similar dry, clear weather prevails over the coastal lowlands around Maracaibo and on the odd bit of South America jutting into the Caribbean, the Península de Paraguaná. Both these Venezuelan locations offer a generous totality of 3m45s or more and the last land-


HISPANIOLA
Santo Domingo
San Juan
PUERTO RICO
St. John's
ANTIGUA
MONTSERRAT
Plymouth
Pointe-à-Pitre
GUADELOUPE
Caribbean Sea
PATH OF TOTALITY
Maximum eclipse at 18h30m UT
Oranjestad
ARUBA
CURAÇAO
Punto Fijo
Willemstad
Maracaibo
par
Caracas
TRINIDAD
Maximum eclipse at 18h00m UT
VENEZUELA
A

The Sky at Mideclipse

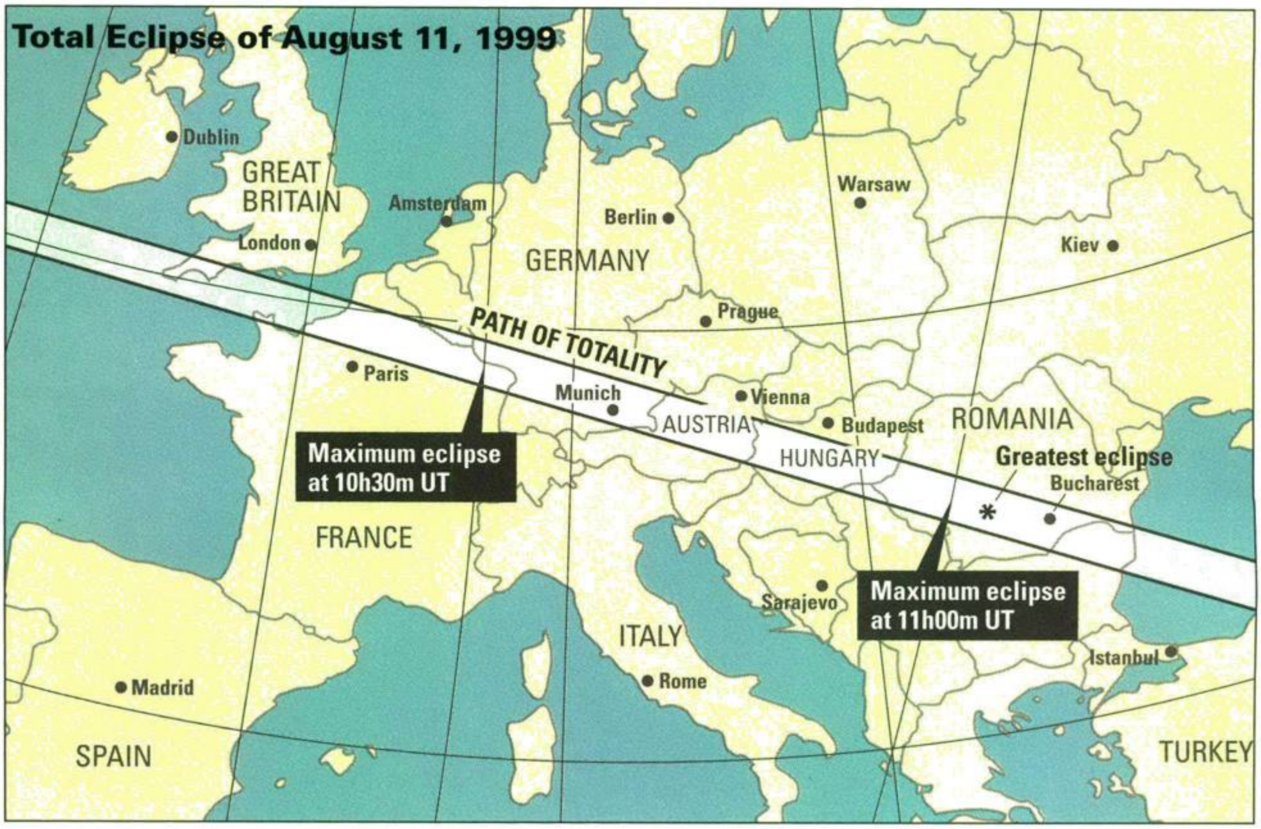

Capella
Deneb
Vega
Aldebaran
Altair
Saturn
Mars
Sun
Rigel
Mercury
Jupiter
Venus
Fomalhaut
Achernar

Objects not to scale

based access to the centerline. From here on, the center of the shadow crosses only ocean.

Just off the northern coast of Venezuela lie the Netherlands Antilles, the "ABC" islands of Aruba, Bonaire, and Curaçao. The path just grazes the north shore of Bonaire, an island mecca for scuba divers. Aruba and Curaçao lie on either side of the centerline. Near their southern and northern tips, respectively, both islands offer about 3m30s of totality, just 13 seconds less than the maximum on the centerline between the islands. Totality is shorter in the capitol cities where most hotels are — 3m06s at Oranjestad on Aruba and 1m58s at Willemstad on Curaçao. But access roads to the beaches and capes on the ends of the islands are good.

Of the two islands, Aruba is better known and offers spectacular beaches, but weather prospects are



equally good on Curaçao. Both islands are largely desert, enjoying sunshine during 70 to 80 percent of the daytime hours, and February ranks as their sunniest month.

The eclipse occurs about 2:15 p.m. local time with the Sun 60° high in the southwestern sky. Midafternoon temperatures will be in the mid-80s F (30° C), but be prepared for gusty winds, especially on exposed points of land. On an inspection trip in early March 1996, I found scattered cumulus clouds could build up during the day over the islands and just offshore. A quick trip a few kilometers down the island could mean the difference between being under clear skies and being under a small but disastrous cloud. Mobility may be important, even on these 30 kilometer long islands.

In addition, in NASA's official guide to this eclipse, Reference Publication 1383, meteorologist Jay Anderson warns "thin high level cirrus is endemic throughout tropical and subtropical latitudes, and observers should not expect pure blue skies at any location for this eclipse." This is just by way of warning — there are no guaranteed eclipses. Remember Hawaii in 1991?

Nevertheless, at a latitude of 12° north, Aruba and Curaçao offer some of the most attractive options for an island vacation. Both are former Dutch colonies, with first-class hotels, restaurants, duty-free shopping districts, camera stores, dive shops, and all the tourist amenities. Everyone on these cosmopolitan islands speaks English, and most citizens are fluent in Dutch, Spanish, Portuguese, and Papiamento, a local dialect. Businesses accept U. S. dollars and hotels have North American 110-volt AC outlets as well as European 220-volt plugs. (I had no problem charging a camcorder.) The drinking water is wonderful — it's pure distilled seawater. As a bonus, the weekend prior to the Thursday afternoon eclipse is Carnival.

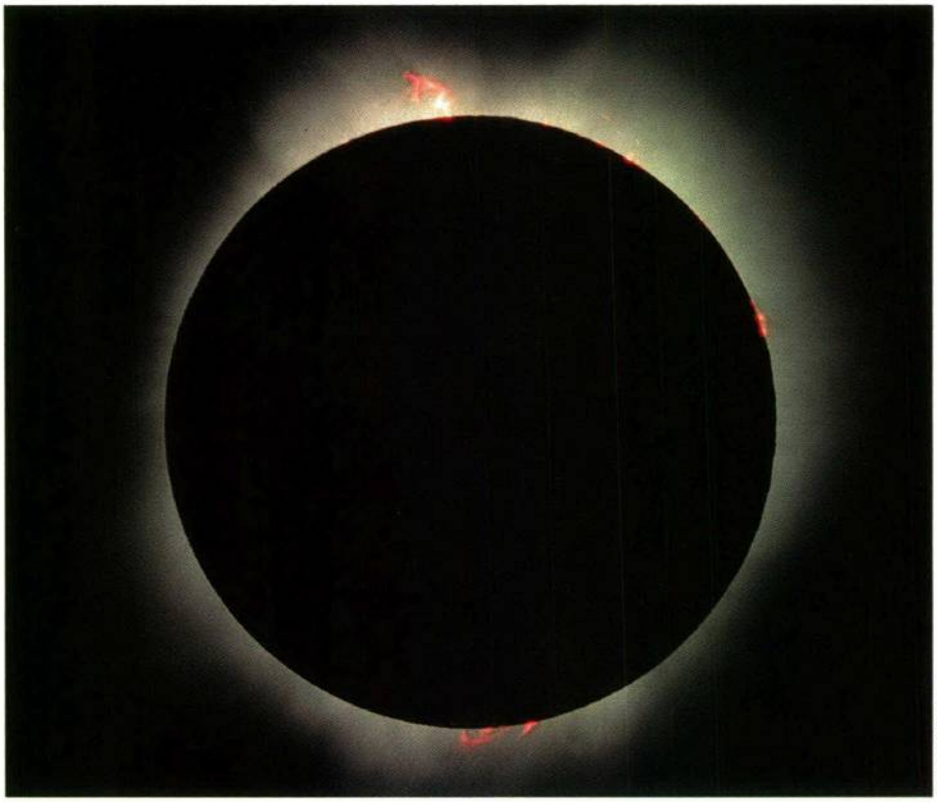
While thousands watch from the islands, thousands more will view the eclipse from sea. Just about every Caribbean cruise line is offering an eclipse sailing in February 1998, with port stops at several islands and eclipse day at sea somewhere on the centerline. Eclipse cruises are an attractive option offering mobility to chase clear skies, great food, centerline access for maximum totality, great food, educational lectures, great food, luxury service and, at the end of each day, more great food!

Some of the largest cruise ships in the world ply these waters every winter, offering surprisingly stable platforms for photography and casual night-sky viewing. Now don't bring your 10-inch Schmidt-Cassegrain telescope, but telephoto lenses up to 400mm focal length can yield excellent eclipse portraits from on deck.

As the eclipse path leaves the Caribbean, it passes over the Leeward Islands of Antigua, Guadeloupe, and Montserrat. Maximum totality on Antigua is 2m47s, while on Guadeloupe and Montserrat, it's about 3 minutes. At sea, totality on the centerline north of Guadeloupe is 3m16s. Clear-sky prospects on these islands are slightly less than on Aruba and Curaçao, about 50 to 60 percent, and are more affected by local mountains. One of those peaks on Montserrat erupted in 1996, prompting evacuation of nearby Plymouth. If an adventurous vacation combining active volcanos and astronomy appeals to you, Montserrat is the place to go.

Eclipse in Europe: August 1999

Whether 1999 is the last or second-last year of the 20th century will be argued back and forth for the next three years. Regardless, this is the last total solar eclipse of the 20th century — there is no total in 2000. And what a way to end the century.



William Sterne, Jr.

As the decade winds down and solar activity approaches its maximum level, totality should reveal plenty of prominences.

Not since 1961 has the Moon's umbral shadow crossed Europe. Tens of millions of people live in or near the path of totality. The vacation destinations are endless — in England: the city of Plymouth and the counties of Cornwall and western Devon; in France: Reims, Nancy, Strasbourg, and the Moselle Valley; in Germany: Mannheim, Stuttgart, Munich, and the upper reaches of the Danube; in Austria: Salzburg and the eastern Alps. On August 11, all will experience between 2m00s (England) and 2m20s (Austria) of totality around noon local time.

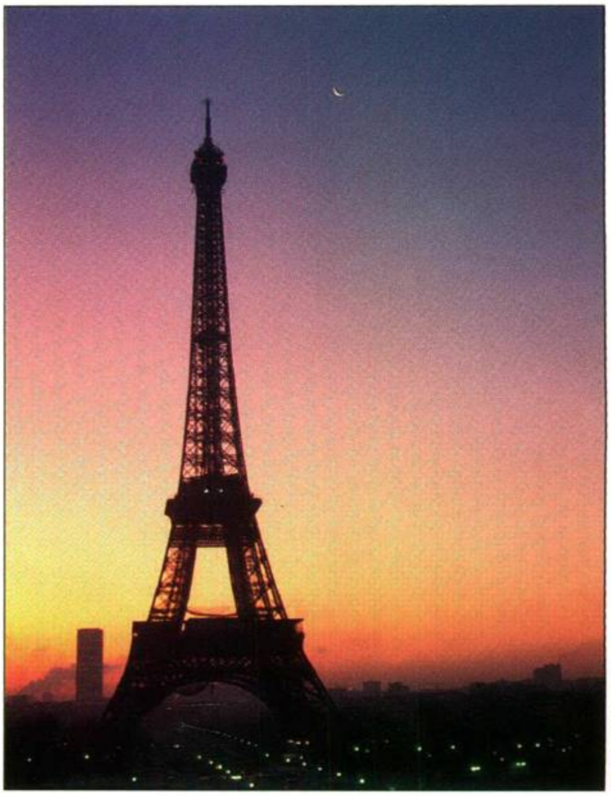
The eclipse reaches its maximum of 2m23s as it crosses the plains of Hungary (south of Budapest) and Romania, with Bucharest ideally located on the centerline near greatest eclipse. The shadow departs Europe over the sunny resort coasts of Romania and Bulgaria on the Black Sea. At the next landfall, the shadow races over central and eastern Turkey, then over northern Iraq and central Iran.

While Iran and Iraq offer superb skies, their political climate is less than ideal for most North American *eclipse chasers*. Turkey offers excellent chances of clear skies along with a rich array of natural wonders and historic sites.

In England and Europe no single weather pattern dominates. One day can be clear, the next cloudy. Mobility and the ability to cross borders and move fast may be the keys to success in Western Europe. But think of the possibilities for a once-in-a-lifetime astronomical experience: the eclipsed Sun glowing eerily over the Alps or beside the spires of a medieval cathedral. Quite an experience to add to your collection.

Of course, if you miss these three eclipses, you can always begin your collection in the 21st century. On an African eclipse safari in June 2001 perhaps? □

Alan Dyer, a former associate editor at ASTRONOMY, is a writer, producer, and eclipse tour organizer with the Calgary Science Centre in Canada. February 1998 will mark his fifth time standing in the Moon's shadow.



Olivier de Goursac

The famed City of Lights lies just 20 kilometers south of the path of totality in August 1999. The last total eclipse of the century will be the first to bring darkness to Europe in 38 years.

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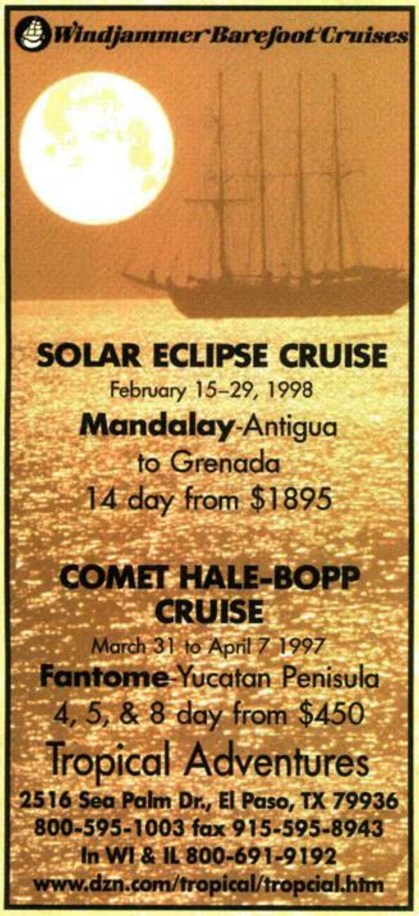

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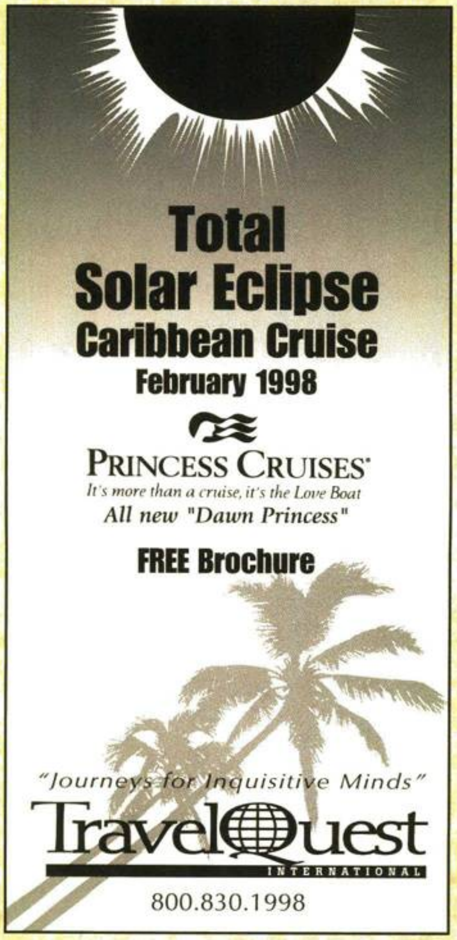

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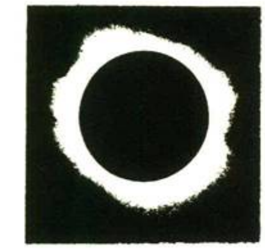

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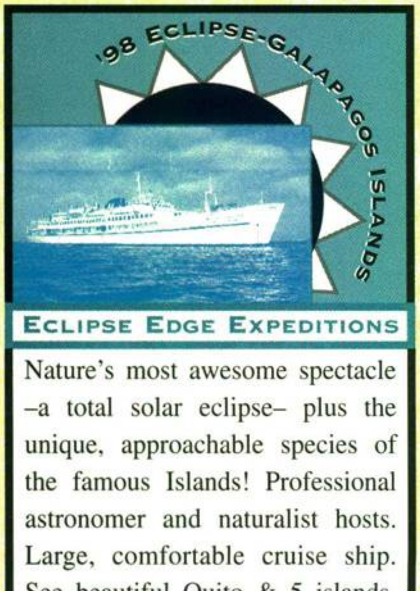

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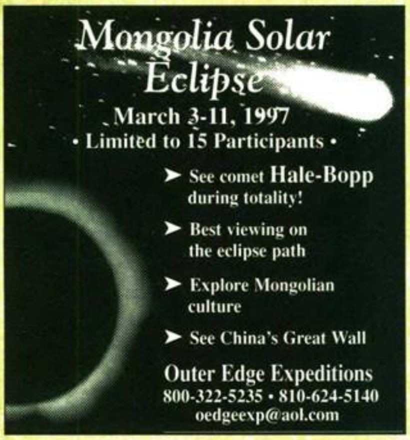

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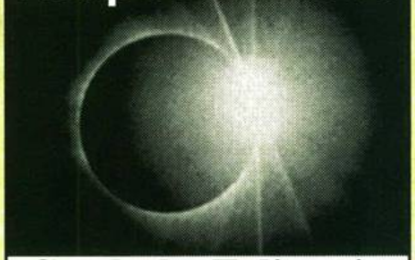

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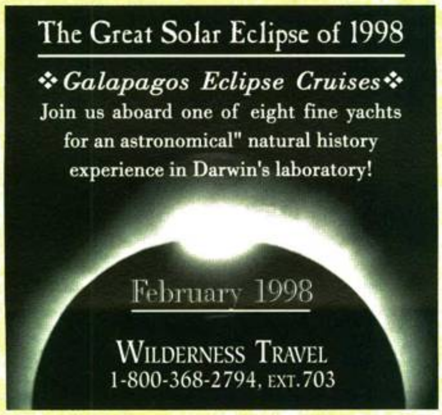

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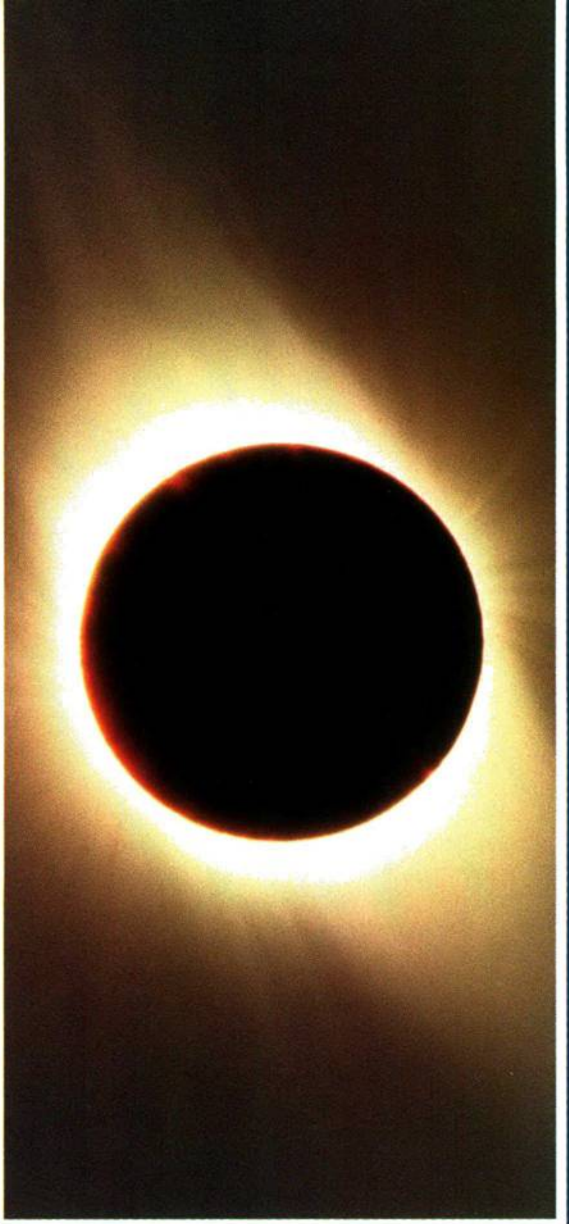

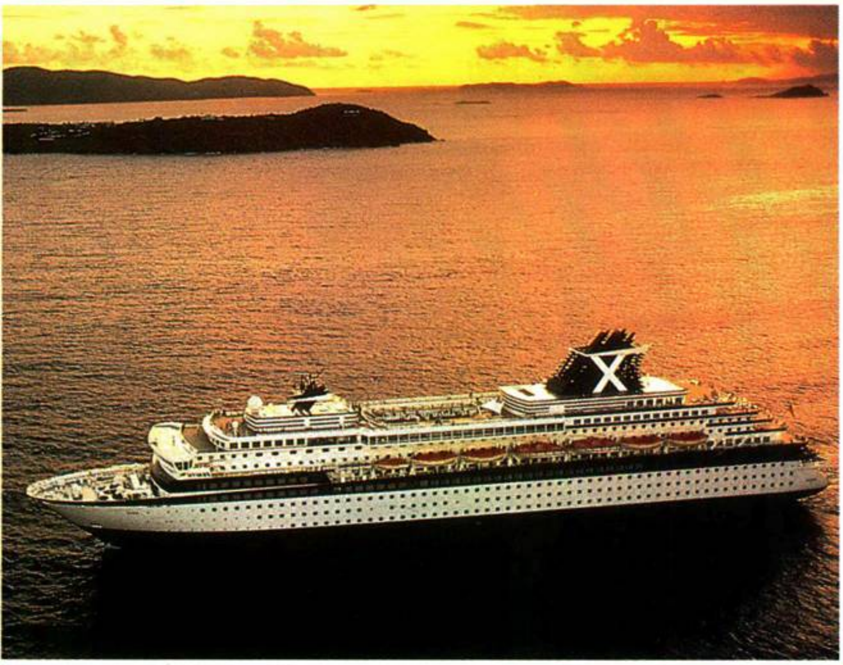

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Eclipse photo taken by Ernest Piini.

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RealSky CD includes images of the entire northern sky down to –15° declination (the approximate location of Sirius) at an angular resolution of 1.7 arcseconds, to reveals stars as faint as 19th magnitude. Sample images may be viewed at the ASP web site at www.aspsky.org. Faint objects show compression artifacts at about 14th magnitude.

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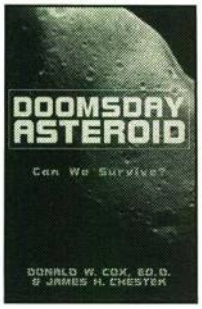

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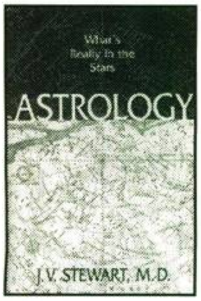

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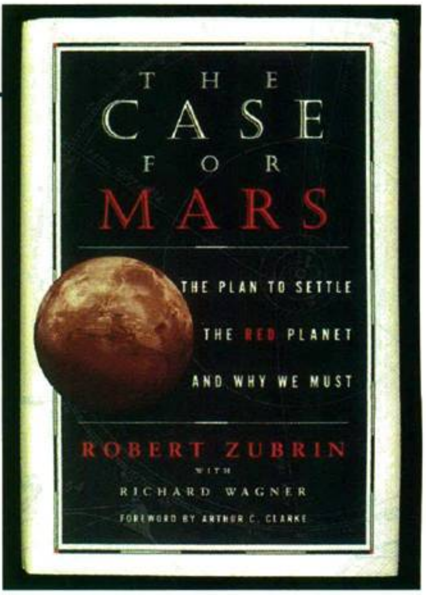
THE CASE FOR MARS
THE PLAN TO SETTLE THE RED PLANET AND WHY WE MUST
ROBERT ZUBRIN
WITH
RICHARD WAGNER
FOREWORD BY ARTHUR C. CLARKE

The Case for Mars: The Plan to Settle the Red Planet and Why We Must

Robert Zubrin with Richard Wagner, 328 pages, Simon and Schuster, New York, 1996; ISBN 0-684-82757-3, hardcover, $25.

In 1961, John F. Kennedy challenged America to place a man on the Moon before the end of the decade. At the time of his speech there were no firm plans on how to accomplish this. Visions born of Buck Rogers foresaw a winged spaceship flying directly to the Moon and descending to the surface, later to blast off and return to Earth in the same condition that it had left. This Buck Rogers approach shows how difficult it is to break from conventional dogma.

But NASA's early rockets were exploding shortly after takeoff. Aerospace engineers could not envision them backing down on the Moon without a pre-constructed pad, let alone powering up again and returning to Earth. Thus, in time was born the "component disposal system," whereby a Saturn V rocket weighing 3,200 tons lifted off, and a 6-ton capsule splashed down. This proved to be successful for lunar missions.

While Apollo was still active, advocates of further space exploration were setting their sights on the next obvious goal: Mars. But that was before funding was cut as a response to public apathy and a re-direction of national priorities. It's been 20 years and Mars is still there.

In July 1989, George Bush initiated a study on human exploration of Mars. The plan called for large hangars, a fuel depot, crew quarters and the like, all in Earth orbit, supplied by heavy-lift vehicles ferrying supplies and fuel. This enormous, complex array of facilities would be used to construct and service trans-lunar ships that would, in turn, construct a gigantic (1,000 ton) martian ship in lunar orbit. From that point the ship, carrying all the fuel and supplies, would complete an 18-month round-trip to the planet. The bottom line was $450 billion — just at the time when America was coming to grips with a multi-trillion-dollar national debt.

In *The Case for Mars*, Robert Zubrin, a former senior engineer at Lockheed Martin and the current executive committee chairman of the National Space Society, addresses the challenges of manned exploration of Mars by attacking the same type of dogma, ingrained misconceptions, and structured thinking that abounded in the early days of manned spaceflight. This book outlines, in generous detail, a very plausible and workable method by which many manned flights to Mars could be accomplished at a fraction of the $450 billion cost.

Virtually everyone thinks of going to Mars in the same manner as going to the Moon. We assume that a spaceship must carry all the fuel needed for the entire round-trip and surface exploration, just as was the case in Apollo. This store of propellants constitutes the vast majority of the weight of the craft, including the weight of the large, insulated tanks necessary to transport it. This problem has been put on the back burner while science and the public patiently await the advent of nuclear propulsion technology. Zubrin compares this to Columbus waiting on the dock for the invention of the 747.

Zubrin reminds the reader that Mars is significantly friendlier than the Moon. Mars provides several key elements that could play an active role in a flight. Unlike the Moon, Mars has an atmosphere. While it is admittedly thin, it is 95 percent carbon dioxide. Traditional thinking informs us that carbon dioxide is waste and of little benefit. Zubrin advocates sending an unmanned vehicle to the martian surface with liquid hydrogen, a small nuclear reactor, and empty storage tanks. Once on the surface, this unit could easily produce methane from the stores of hydrogen and the indigenous carbon dioxide. Once the unit radios to Earth that the tanks are full, a manned flight could be launched with only the fuel required for a one-way flight. The fuel for surface exploration and the return flight would be already waiting on the martian surface.

If this sounds a bit risky, Zubrin describes backup systems that could repair and replenish any fuel needed in case of an emergency or breakdown of the advance unit.

This book does much more than merely provide ways to save return-trip fuel. Zubrin points out that roughly 2 million cubic kilometers of water ice have been identified in Mars' north polar cap, with potential sub-surface deposits of ice and liquid water planet-wide. This water could be reduced to its component hydrogen and oxygen, providing oxygen and liquid water for the explorers while eliminating the need to carry hydrogen to the planet on later trips. Zubrin also discusses the building of habitable colonies, producing plastics, recovering metals, and eventually terraforming the surface.

The Case for Mars presents one man's idea of an alternative to the current viewpoint. Zubrin goes to great lengths to detail and defend his ideas. However there are times when he glosses over potential roadblocks in his plan. But in Zubrin's defense, his plan does not require new technologies or pie-in-the-sky funding. Everything encompassed in Zubrin's plan takes advantage of technology that is currently on the shelf. I hesitate to use the author's estimates of cost, but the obvious savings in hardware alone, when compared to the current proposal known as the Space Exploration Initiative, could produce results within 20 years at a small fraction of the current estimated cost.

This book may become the most important breakthrough in space exploration in our lifetimes.

— Lee Vande Visse □

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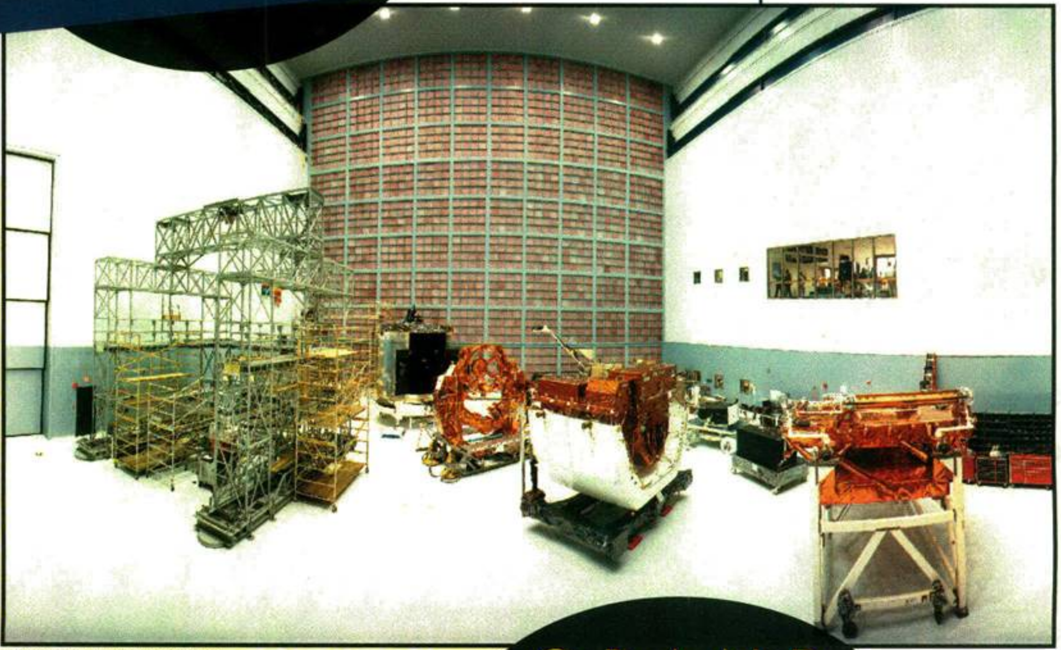

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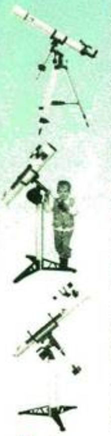

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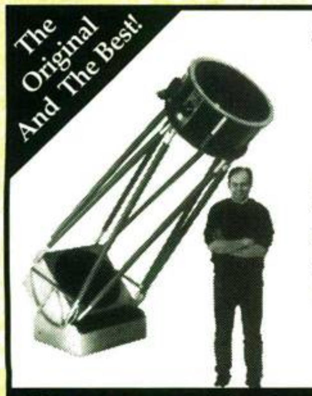

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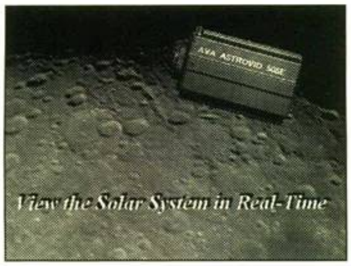

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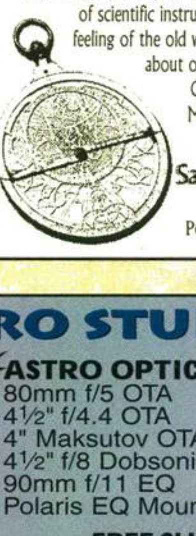

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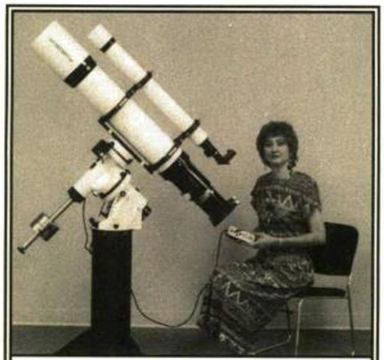

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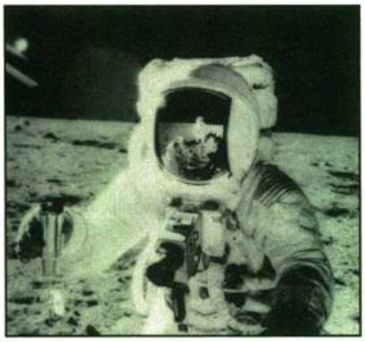

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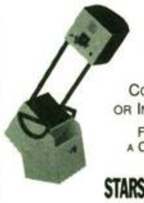

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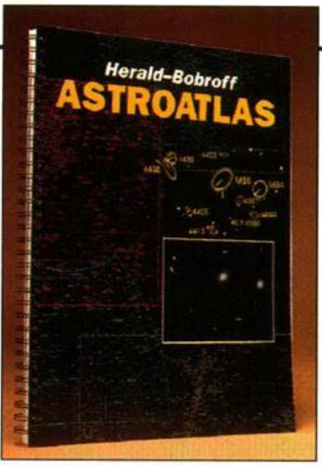

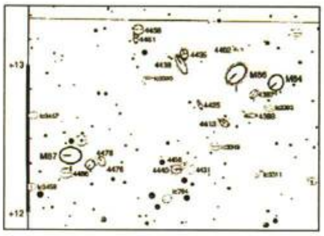

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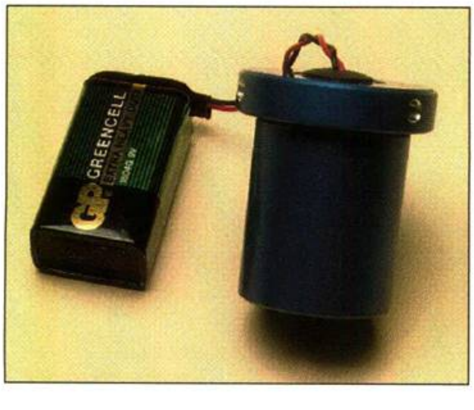

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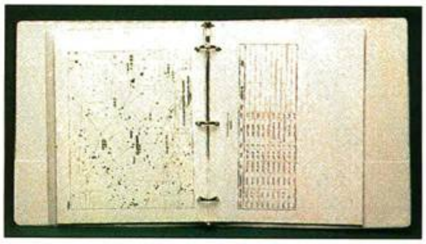

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M & J Enterprises, 3405 Cahuenga Boulevard West, Los Angeles, CA 90068; (800) 967-3300. The Lite Light: $14.95; California residents add 8.25% sales tax.

NEW PRODUCTS

Venus
Unveiled
30

Venus Slide Set

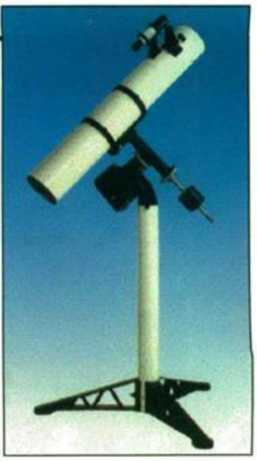
Ireland's Armagh Planetarium offers *Venus Unveiled*, a slide collection of the best imagery returned during Magellan's four-year mission to map the surface of Venus with radar. The 30-slide set includes some pictures taken by Russian landers and the Pioneer Venus Orbiter. Accompanying text lays out a history of Venus exploration, coupled with what planetary scientists currently know about the planet. There's also an explanation detailing what features to note on each slide. Everything comes in a vinyl storage folder.

Hansen Planetarium Publications, 1845 South 300 West, #A, Salt Lake City, UT 84115-1804; (801) 483-5400; fax, (801) 483-5484. Venus Unveiled Slide Set, Item #1587-3: $33.75, plus shipping and handling.

Binocular Astronomy Kit

Star Light is a folder of reference materials specifically designed for the beginning skywatcher who uses binoculars. A booklet lays out how to observe with binoculars and what to look for. The kit also features a small plastic planisphere that dials in what constellations are in the night sky for any time of night during any month. Other items in the packet include a table of the best meteor showers, a three-year planet locator, a finder chart for Comet Hale-Bopp, and a observing log you can photocopy.

David Chandler Company, P.O. Box 309, La Verne, CA 91750; (800) 516-9756; (909) 988-5678; fax, (909) 988-5618; e-mail, dschandler@frumble.claremont.edu; Web page, http://www.csz.com/dschandler. Star Light: $13.95, plus shipping — $3 domestic, $6 foreign.



4.5-inch Motorized Reflector Telescope

The Sovietski Collection, importers of optics from the former Soviet Union, has teamed up with Russia's Novosibirsk Military Optical Factory in Siberia to offer a German equatorial reflecting telescope. The scope's 4½-inch f/6.3 optics are housed in an aluminum tube fitted with a 1¼-inch focuser. The equatorial mount tracks the sky thanks to a clock drive motor. This mount sits on an aluminum pedestal with built-in vibration suppression pads. The scope also comes with a 6x30 finderscope with crosshairs, a 3x Barlow lens, a 25mm Plössl eyepiece, a 15mm Kellner eyepiece, a screw-in filter set (blue, red, green, yellow, and gray), and a camera bracket for eyepiece projection and afocal astrophotography. Everything comes in a wooden carrying case. Sovietski warranties the scope and mount for one year, and offers a ten-day money-back satisfaction guaranty.

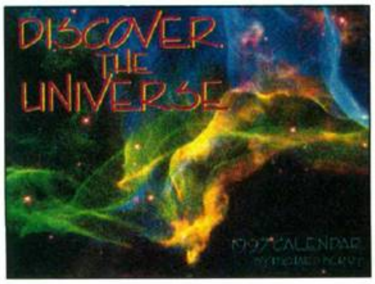
Sovietski Collection, 3450 Kurtz Street, Suite #C, San Diego, CA 92110; (619) 294-2000; (800) 442-0002; fax, (619) 294-2500; e-mail, fulcrum@sovietski.com; Web site, http://www.sovietski.com. The 4.5-inch Motorized Reflector Telescope: $699; California residents add 8.25% sales tax.

Tapes of the Night Sky

Tapes of the Night Sky

The Astronomical Society of the Pacific has updated a taped program that takes listeners on a seasonal tour of the night sky. Two cassettes offer four 30-minute narratives, one for each season. A narrator walks through each constellation to highlight any interesting stars, deep-sky objects, or stories from mythology. A booklet has interpretive diagrams and a complete script for each tape. A 5½-inch star wheel lets you dial in how the sky looks for any time of year or night, from anywhere in the mid-northern latitudes. Everything comes packed in a 6" by 6" carrying case.

Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112; (415) 337-1100; fax, (415) 337-5205; e-mail, asp@stars.sfsu.edu. Tapes of the Night Sky: $24.95; California residents add 8.25% sales tax.



Astronomical Wall Calendar

Former ASTRONOMY editor Richard Berry produces the *Discover the Universe* wall calendar for 1997. Each month features two theme photos, one full-page and another that runs above a small explanation on the calendar page. The calendar page also has a thumbnail diagram and description of the constellations visible that month. Date boxes present interesting astronomical phenomena, astronomy history trivia, major Moon phases, and civic holidays. The opening box lays out where the Sun and planets will be for the coming month. *Discover the Universe* is printed on semigloss paper and features a saddlestitch binding.

FEBRUARY 1997

Tide-mark Press, P.O. Box 280311, East Hartford CT 06128-0311; (860) 289-0363; (800) 338-2508; fax, (860) 289-2654. The 1997 Discover the Universe wall calendar: $10.99.

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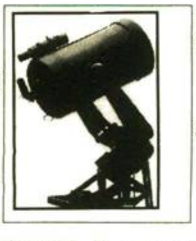

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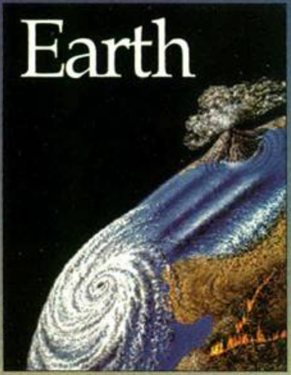

Four Disasters That Shaped The World
Floods and storms that make Hurricane Andrew look like a mild breeze have changed the face of our planet. Our special report looks at how four such cataclysms came to pass and the marks they left behind.

Desert in Disguise
The grassy slopes and marshes of Nebraska's Sand Hills shelter a variety of wildlife and people — and cover a sea of sand dunes that once rivaled the Sahara. If the planet gets a bit warmer, it could do so again.

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MEETINGS EVENTS

February 3-9
Winter Star Party, Camp Wesumkee, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact Bob Grant, 5401 S.W. 110 Avenue, Miami, FL 33165, (305) 595-8778, bginsofl@aol.com.

February 13-16
MEPCO '97, Meeting of European Planetary and Cometary Observers, Bruder-Klaus-Heim, Violau, Bavaria, Germany. Contact Wolfgang Meyer, Martin-Str. 1, 12167 Berlin, Germany, http://www.geocities.com/CapeCanaveral/5599/mepco.html, or Daniel Fischer, dfischer@astro.uni-bonn.de.

February 15
Wagman Winterfest, Nicholas E. Wagman Observatory, Mahaffey Road, Deer Lakes Regional Park, Russellton, Pennsylvania. Free. Contact (412) 224-2510, pzapadka@fyi.net, Web: http://trfn.clpgh.org/orgs/aaap.

March 1
Southern Michigan Amateur Astronomy Conference (now SMAAC – formerly the 'Freeze Out'), Eastern Michigan University campus, Strong Auditorium, Ypsilanti, Michigan. Contact Norbert Vance at EMU Physics & Astronomy, 303 Strong, Ypsilanti, MI 48197, (313) 487-4144, phy_vance@online.emich.edu, Web: http://www.emich.edu.

March 7-9
First Annual Highlands Stargaze, Nine Mile Grade Campground, Kissimmee River between Sebring and Okeechobee, Florida. Contact Richard Lindblom, 2130 Gresham Street, Sebring, FL 33872, (941) 655-0131, lindblom@ct.net.

March 7-9
STARPAW97, Practical Astronomical Weekend, Domein De Maat, Mol-Postel, Belgium. Organized by the Andromeda Astronomical Society Mol. Contact Josch Hambsch, Oude Bleken 12, B-2400 Mol, 32-0-14-310507, hambsch@irmm.jrc.be.

Please submit club announcements four months in advance to Meetings and Events, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com.

RESOURCES PHOTOFACTS

Blowing Cosmic Bubbles (page 36)

"Ashes to Ashes and Dust to Dust," by David J. Eicher, ASTRONOMY, May 1994. Explains how planetary nebulae give astronomers insight into stellar death.

"Winds of Change," by Adam Frank, *Discover*, June 1994. An excellent introduction to the formation of planetary nebulae.

Seeing Rogue Comets (page 80)

"Motes in the Solar System's Eye," by Thomas Brophy, ASTRONOMY, May 1993. This article explains how dust penetrates the solar system from deep space.

Comet, by Carl Sagan and Ann Druyan (Random House, 1985). Although somewhat out-of-date, this book contains a beautifully written account of how comets form.

Eclipse (page 90)

Chasing the Shadow: An Observer's Guide to Eclipses, by Joel K. Harris and Richard L. Talcott (Kalmbach, 1994). All a chaser needs to know about planning a trip to view an eclipse.

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p. 64: Comet Hale-Bopp, Chris Schur, 12-inch f/5 reflector, hypered Kodak Pro 400 PPF, 20 minutes; **p. 69:** Mars, December 25, 1990, Don Parker, 16-inch f/6 reflector working at f/76, Ektachrome 200, 6 seconds; **p. 72, top:** Full Moon, Alan Dyer, 2000mm f/10, 1/250 second on Kodak Ektachrome 200; **p. 72, bottom:** Jupiter and Great Red Spot, Franz Kufer, 12-inch f/18 Cassegrain, Scotchrome 100, 1 second; **p. 73:** Mira at maximum, Ronald Royer, 50mm f/2.8, Fujichrome 1600D, 10 minutes; **p. 76, top to bottom:** Comet Hale-Bopp, Erich Meyer and Herbert Raab, 300mm f/5.2 SCT, ST-6 CCD camera, 30 seconds; Naruyoshi Ando, 100mm f/6.4 BORG, Fujicolor Super HG-800, 10 minutes; Todd Hargis, 16-inch f/4.5 reflector at 131x, Vince and Maggie Farnsworth, 4-inch f/5 refractor, guided with an ST-4 CCD camera, unhypered Fujicolor Super G 800, 20 minutes; **p. 80, left to right:** Comet Hale-Bopp, Gordon Garradd, 10-inch f/4.1 Newtonian and HI-SIS CCD camera, five 60-second exposures; **p. 81, bottom:** Chris Schur, 135mm f/4, Fuji 400 Super G Plus, 15 minutes.

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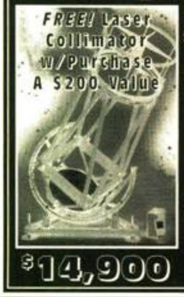

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AD INDEX

Addison-Wesley Longman Publishing 31
Adirondack Video Astronomy 107
Adorama 62, 63, 127
Alien Tourist Company 107
American Express 96
Analytical Scientific 117, 127
Astro-Physics 109
Astronomical Adventures 108
Astronomics 29, 58, 110
Astronomy Shoppe 116, 127
Astrosystems, Inc 108
Ball Photo Supply 116
Joseph R. Beck 96
Bergen County Camera 127
Berger Brothers Camera Exchange 116
Bethany Sciences 108
Blue Sky Pages 116, 117
CBH Travel 97
Camera Bug 116, 127
Captain's Nautical Supplies 127
Michael I Casper Meteorites 109
CC Sales/Camera Corner 127
Celestron International 18, 101, 130
Central Camera Co. 108
Coulter Optical 14
Crazy Ed Optical 109
Cruise Holidays 96, 97
Cruises Cruises Cruises, Inc. 98
Dark Matter Images 109
Destiny 110
Dover Photo Supply 127
Eagle Optics 117
Edmund Scientific Company 21
Edward R. Hamilton, Bookseller 109
Equatorial Platforms 106
FC Meichsner Company 127
Fell's Handicrafts 109
Focus Camera 115
The Franklin Mint 17
Future Games 117
Gayety Travel 96
Helmer Publishing 106
Innovations in Travel 97
International Optics Ltd 106
Into the Wind/The Kite Source 108
JMB Inc 14
Jim Kendrick Studio 107
Jim's Mobile Industries 21
Kalmbach Publishing Company ....22, 99, ...104, 105, 114
Khan Scope Centre 117
Knollwood Books 109
L&T Instruments/Harrison 117
Learning Technologies, Inc. 108
Lumicon 52, 53, 127
M&J Enterprises 108
Makewood Products 109
Nick Marella 109
Marketplace pages ....96, 97, 98 ....106, 107, 108, 109, 110
Meade Instruments Corporation ....2, 3, 7, ...8, 9, 10, 11, 12, 13, 103
Meta Research 98
Michael David Ward Productions 109
Montrose Travel 96
Mountain Skies Astronomical Society 108
Murnaghan 103
Mystic Stamp Company 15
Network Cybernetics Corporation 107
Newbridge Communications, Inc. 19
Newport Glass Works 106
Novagraphics 109
Nurnberg Scientific 116
Obsession Telescopes 106
Oceanside Photo & Telescope 127
Optical Guidance Systems 116
Orion Telescope Center 33, 34, 35
Outer Edge Expeditions 98
Palomar Optical Supply 106
Paradon Industries 27
Pocono Mountain Optics 44, 45, 127
Procyon Systems 21
Prometheus Books 102
Rainbow Symphony 107
Reed Drabick, Inc. 58
Rex's Astrostuff 107, 116
Rivers Camera Shop 22
Robert A Haag-Meteorites 108
Santa Barbara Instrument Group 23
Sarasota Camera Exchange 116
Saunders & Cooke 107
Science Connection 110
Scope City 58, 127
Shutan Camera & Video 59
Sky Planner Enterprises 103
Sky Valley Scopes 110
Sky Watchers Inn 108
Smithy 110
Software Bisque 25
Software Systems Company 21
Spears Travel 97
Star Gazer Instruments 117
Star Hill Inn 106
Starmaster Portable Telescope 106
Starry Messenger 108
Starsplitter Telescopes 110
Stellar Vision 116, 127
Technical Innovations 14
Tele Vue Optics, Inc 128, 129
Tele Vue Dealer Page 127
Thousand Oaks Optical 16
Travel Exchange, Inc. 98
Travel Quest 97
Travel Wizard 98
Roger W Tuthill, Inc.p 31, 107
Tropical Adventures 97
Twilight Tours 98
University of Arizona 103
Vernonscope 103, 110
Virgo Astronomics 106
White Nights 97
Wholesale Optics 113
Wilderness Travel 96, 98
Wonder Works 116

Get Connected With Mars

Planetary Scientist Jim Bell wants to take us all to Mars.

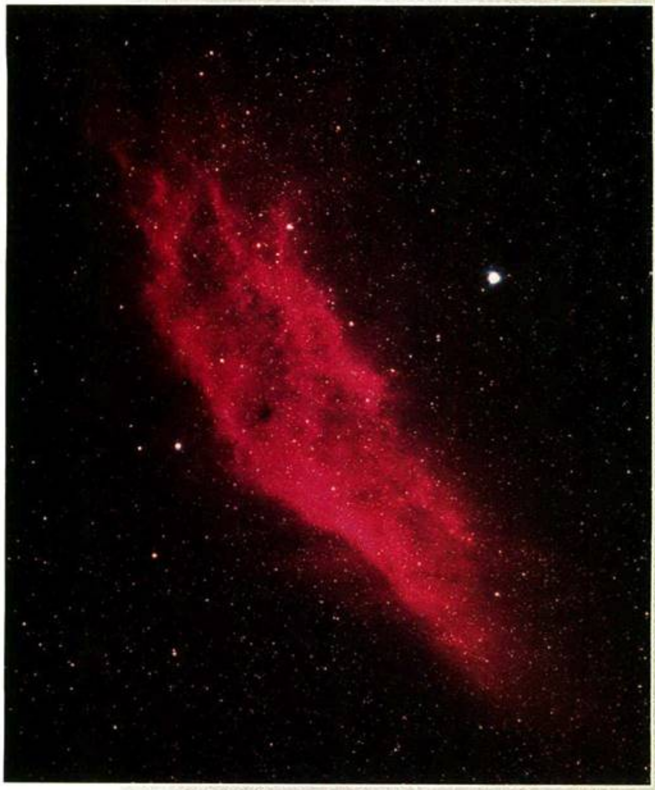
An avid observer of the planets, Bell is pulling together amateur and professional astronomers into an Internet cyber-network called Marswatch.

Marswatch is nothing new. It's been around since the 1960s, a lasting tribute to the dean of Mars observers, the late Charles Capen of Lowell Observatory. The network has compiled observations of the Red Planet from all over the world into one coherent record. Bell's Marswatch will continue to do that, and then some.

In his capacity as a NASA planetary scientist, Bell wants to link ground-based observers electronically with mission scientists who are controlling and collecting data from spacecraft around Mars. His Marswatch web site (http://astrosun.tn.cornell.edu/marsnet/mnhome.html) will work as a clearing house for visual and photographic observations during the upcoming Mars Pathfinder, Mars Surveyor, and Mars '96 missions.

According to Bell, observers can make a direct contribution to these and future missions. Orbiting spacecraft only take in a tiny portion of Mars at any given time for precision, high-resolution views. But what's the rest of the planet doing? "There's a unique opportunity for telescopic observers on Earth to provide global-scale monitoring that will complement

Jupiter, Venus, and Mars over West Australia
Maurice Clark
(160mm f/2.8, Agfachrome 1000 film, 20-second exposure)



The California Nebula in Perseus
George Greaney
(6-inch f/7.1 refractor, Fuji SHG400 film, two 60-minute exposures)

high-resolution spacecraft data," he says.

Bell also sees a role for observers in mission planning. They can keep tabs on how dusty Mars' atmosphere looks, and therefore its warmth, a critical factor in planning Mars Pathfinder's July landing and the entry of probes from Mars '96 in September.

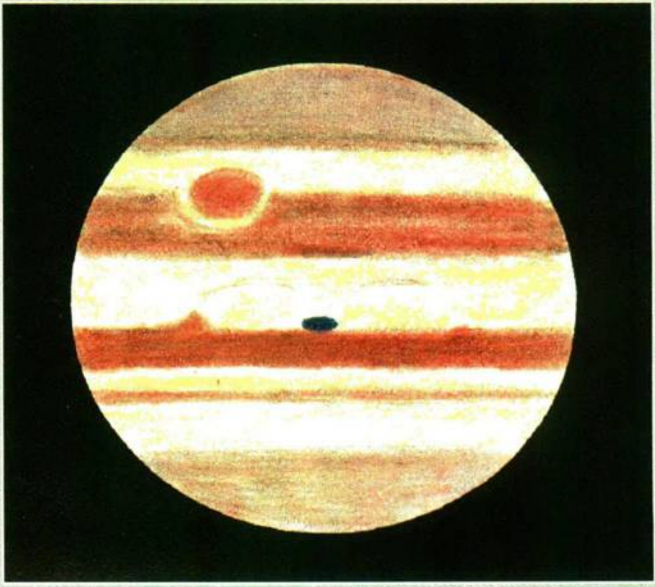
"Knowing how much dust is in the atmosphere during the cruise phase and just before landing will help mission planners design the best possible entry scenarios," says Bell. NASA's even become a partner in the Marswatch effort, setting up a dedicated WWW page and image archive at http://mpf www.jpl.nasa.gov/mpf/marswatch.html.

Of course those who pitch in will have to know what to look for. To that end, Bell encourages interested observers to contact the Association of Lunar and Planetary Observers. They offer training programs, advice, and materials.

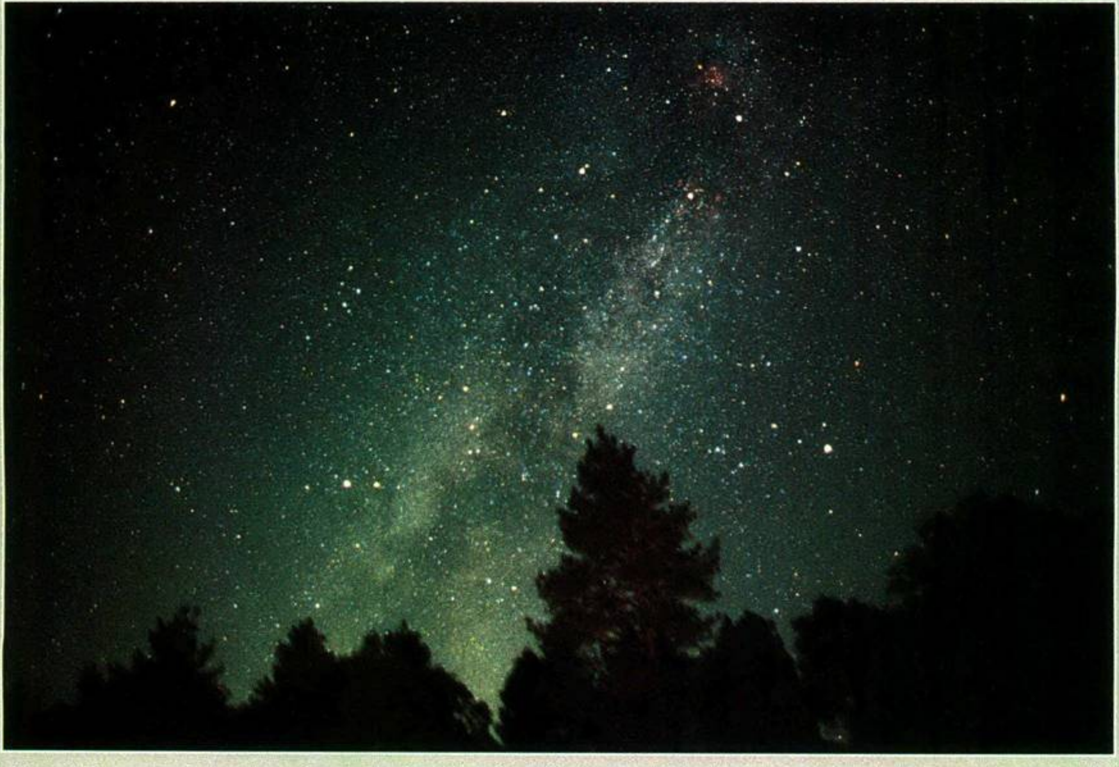
Tell Mars training program coordinators Timothy J. Robertson (2010 Hillgate Way #L, Simi Valley, CA 93065; e-mail, trobert@earthlink.net) and Matthew Will (2112 Austin Drive Springfield, IL 32704; e-mail, 76131.1525@compuserve.com) you're interested in going to Mars. ☐

ASTRONOMY wants to share your observations of the sky with readers. Send reports, sketches, photographs, and disks to John Shibley, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Please label each photo with photo data, name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com

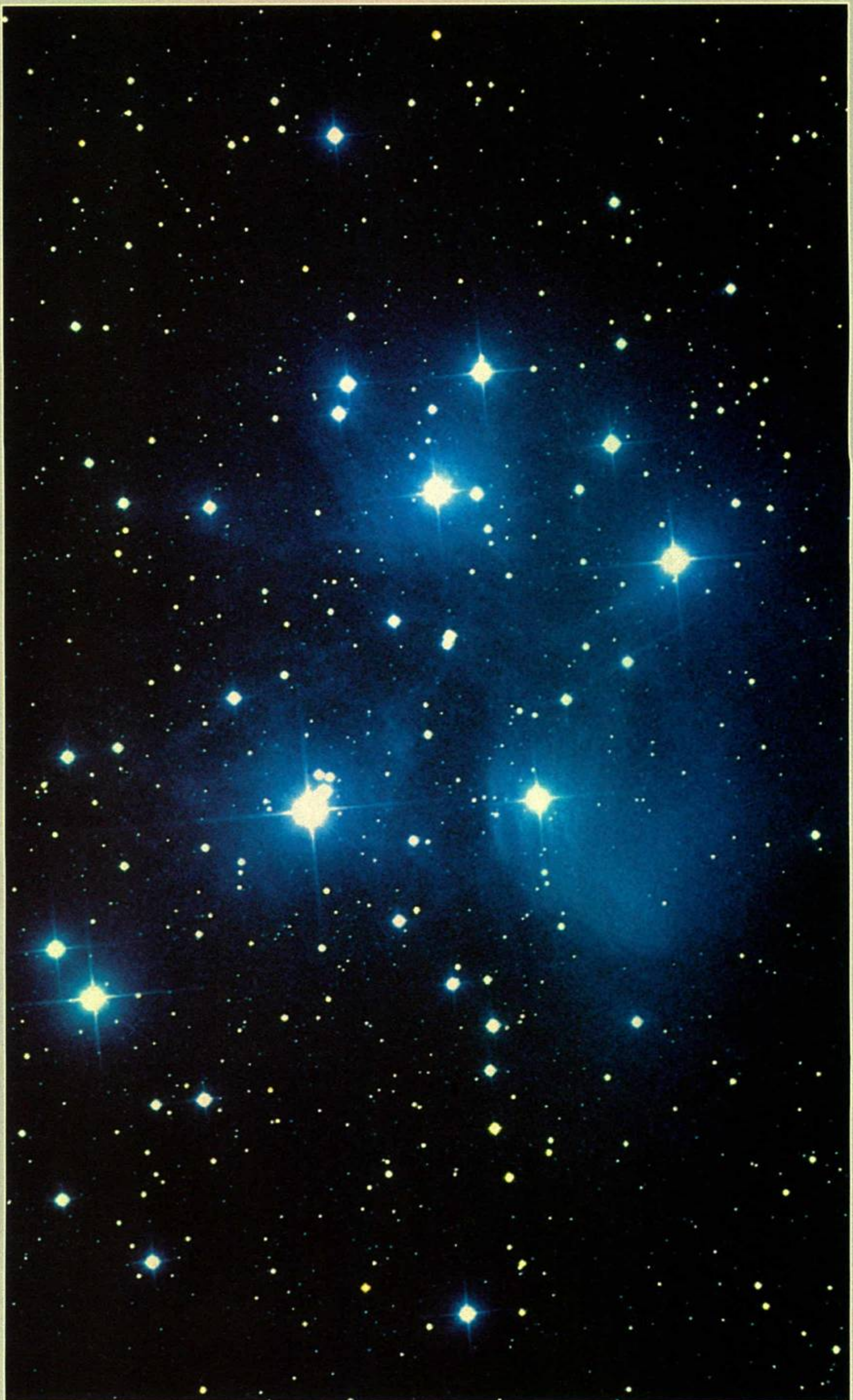
Shuttle Re-Entry, May 29, 1996
Bob Hatfield
(35mm f/2.5, Kodak Royal Gold 400 film, 6-minute exposure)



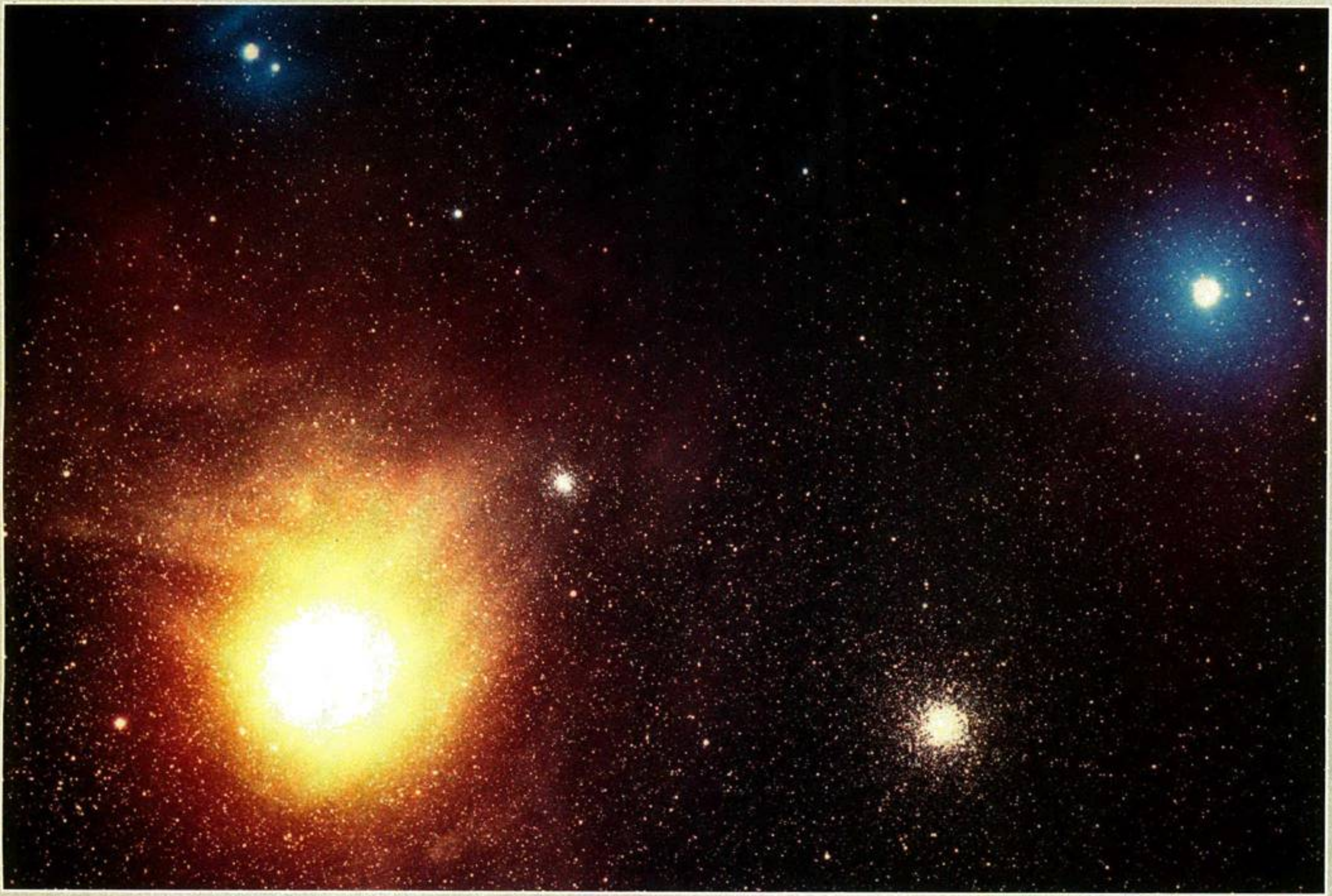
Jupiter Drawn in Color, July 11, 1996
Jim Tomney
(6-inch f/8, 160x)



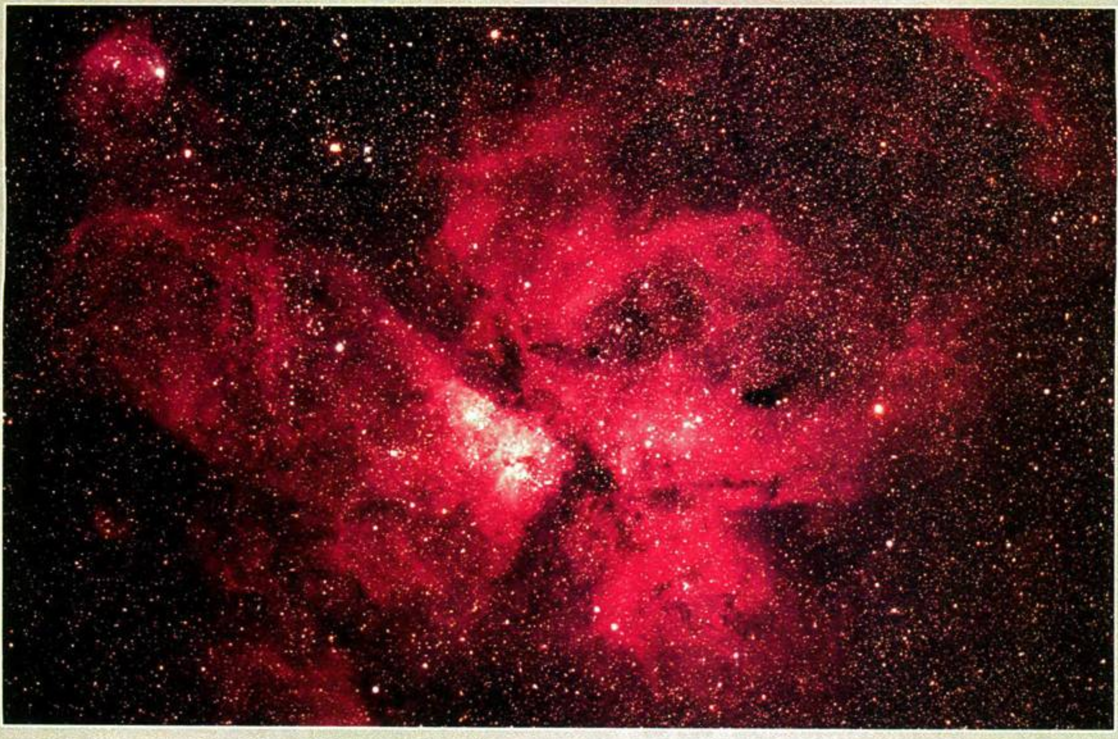
Cygnus Milky Way Sets
Jerry Schad
(24mm f/1.7, Ektachrome P1600 film pushed to ISO 3200, 12-minute exposure)



M45, the Pleiades
Michael Stecker
(8-inch f/4, hypered Fujichrome 100 film, 30-minute exposure)

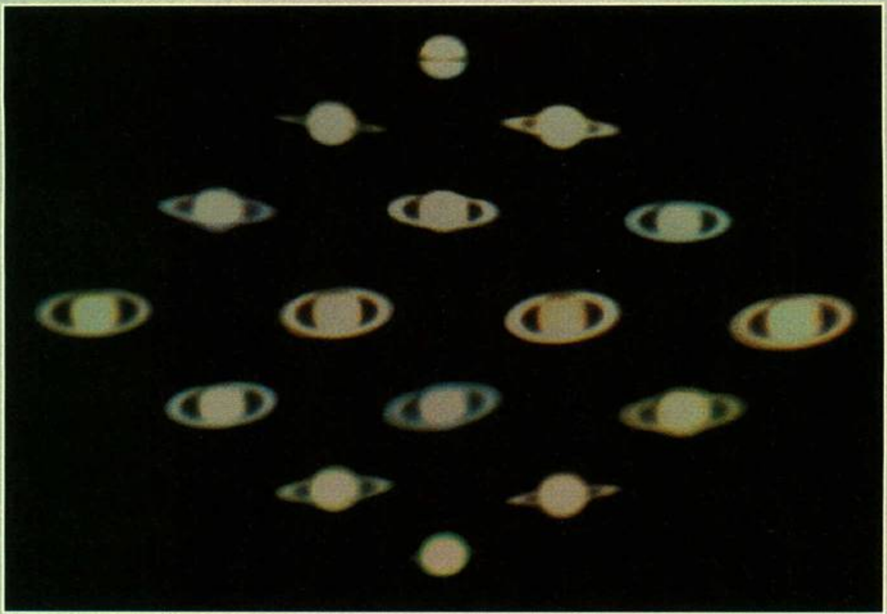


Nebulosity around Antares and M4 in Scorpius
by George Greaney
(6-inch f/7 refractor on a Byers Series II mount with an SBIG autoguider, Fuji SHG400 120 format film, two 60-minute exposures sandwiched together)

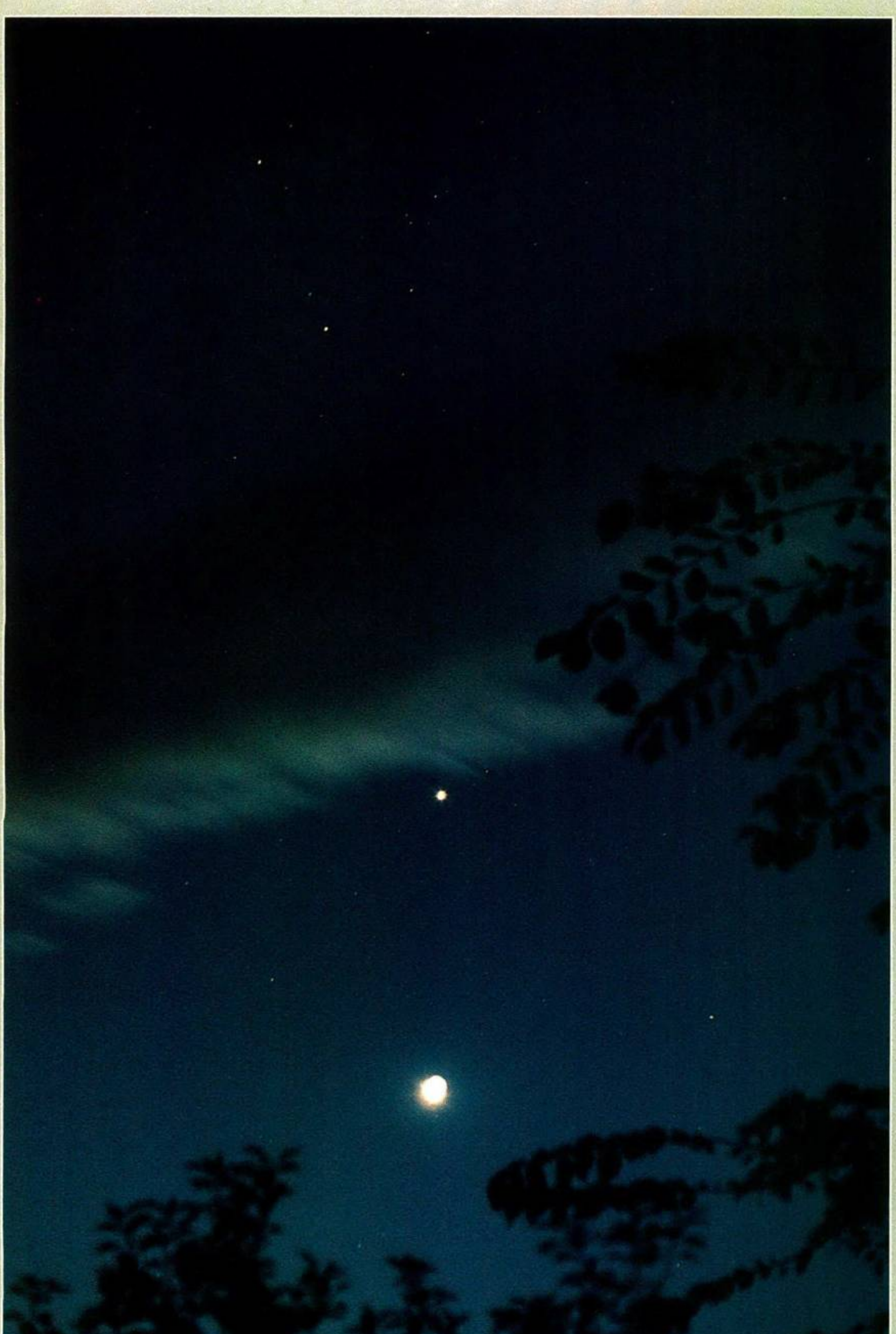


Eta Carinae and NGC 3324
by Michael Stecker
(5-inch f/4.5 refractor, hypered Fuji HG 400 film, two 45-minute exposures sandwiched together)

Star Trails over the Himalayas
Mark Pfetzer
(32mm f/2, Fujichrome Provira 100, 50-minute exposure)



Composite of Saturn between Ring Plane Crossings, 1980-1995
Jim Curry
(1980 is at top, then each year arranged chronologically, top to bottom, left to right, 8-inch f/10 using a 12mm eyepiece for projection, Kodak Ektachrome 400, 4-to 6-second exposures [1980, 1981, 1991-1995], Kodak Ektachrome 200, 10- to 12-second exposures [1982-1990])



Moon, Venus, Pollux, and Castor on September 9, 1996
Randall Wehler
(50mm f/1.4, Ektachrome Elite 200 film, 30-second exposure)

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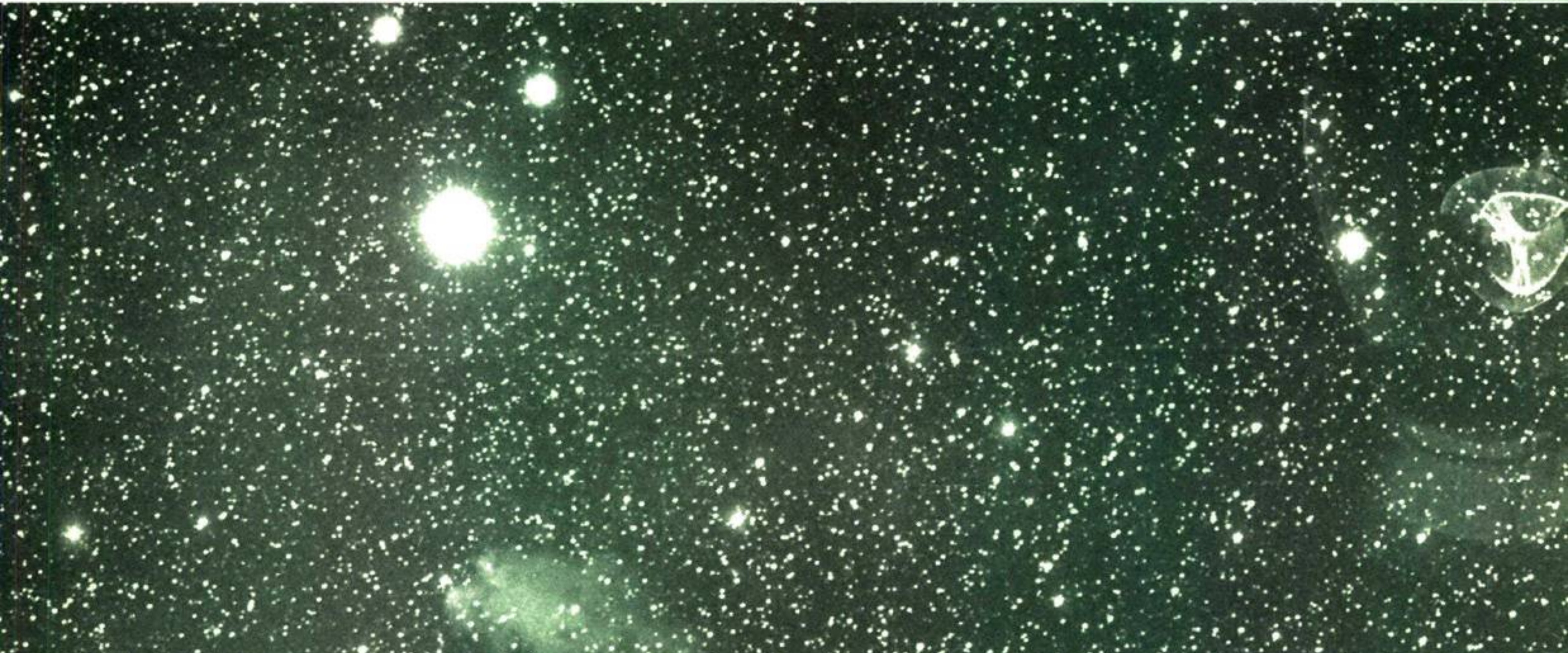

Witch Head Nebula in Eridanus

Chris Schur

(8-inch f/1.5 Schmidt camera, hypered Technical Pan 2415, 10-minute exposure)

The Witch Head is an expanse of dust illuminated by the electric-blue light of Rigel, the brightest star in Orion, which shines from the bottom left corner. The star's brilliance has also created an interesting-looking internal reflection on the upper right corner of this photo. Rigel and its attendant Witch Head shine across 1,400 light-years of space. *Look for Rigel as the Hunter's* left foot; the Witch Head needs a dark sky and something larger than a 12-inch telescope to spot.

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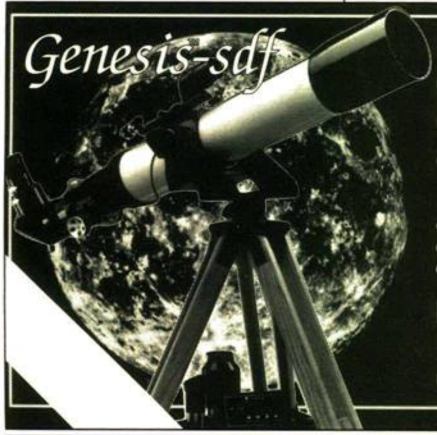

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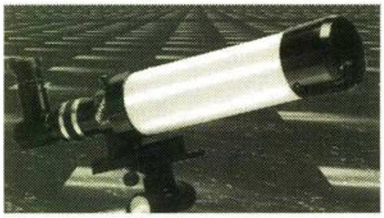

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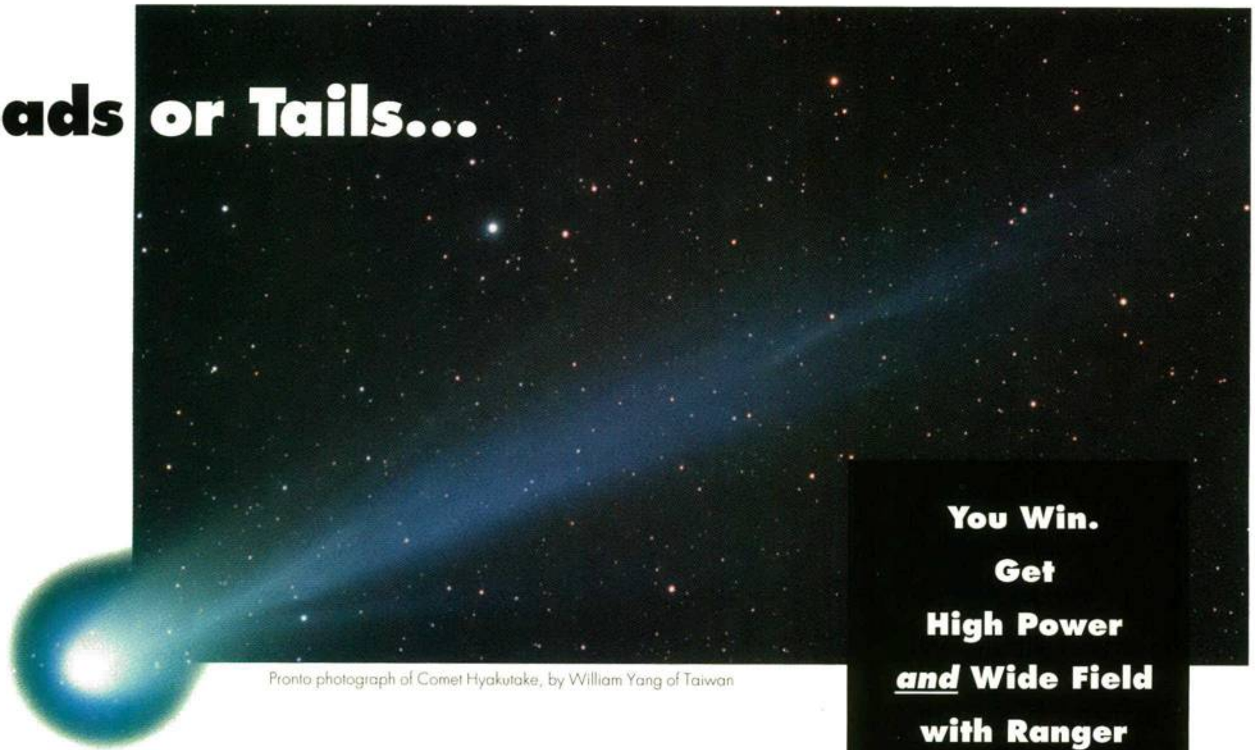

Pronto photograph of Comet Hyakutake, by William Yang of Taiwan

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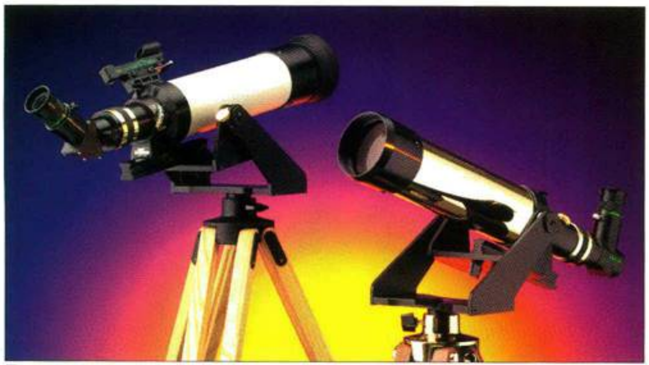

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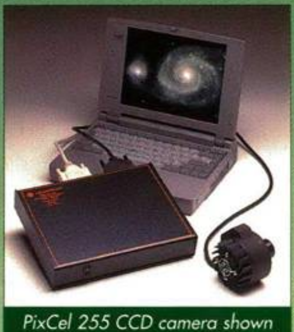

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